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16. Abstract

This final report summarizes the work accomplished under Phase I of the program entitled "Study to Define Arctic Pollution Response Systems and Develop Arctic Oil Pollution Response Project Plans." The objective of Phase I of the program was to determine the most cost effective, environmentally compatible, and technically feasible Coast Guard arctic pollution response system that can be used in projected oil spill scenarios to recover and dispose of spilled oil. The optimum arctic pollution response system was determined by establishing the cost and effectiveness of response for sixteen oil spill response situations, and developing six alternative Coast Guard arctic pollution response systems based on these situations. The optimum system was then identified as the result of a cost effectiveness analysis. The six arctic oil spill scenarios consisted of a gathering pipeline rupture in the nearshore Beaufort Sea, an oil well blowout from a very large reservoir in the nearshore Chukchi Sea, crude oil tanker casualties in Norton Sound and in the Navarin Basin region of the Bering Sea, an oil well blowout from an average sized reservoir in Bristol Bay, and a fuel oil spill resulting from the collision of a fuel oil barge in Unimak Pass. The optimum system provides for a 25% response level for the Norton Sound, Navarin Basin, Bristol Bay, and Unimak Pass scenarios, and a 50% response level for the Beaufort Sea and Chukchi Sea scenarios. Modifications in the optimum system required to extend its capability to subarctic applications in the Great Lakes, the northern rivers, and the northern coastal region were also identified.

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METRIC CONVERSION FACTORS

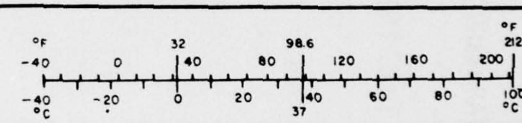
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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APPENDIX B

APPLICATION OF EXISTING AND PLANNED OIL SPILL ABATEMENT TECHNIQUES AND EQUIPMENT TO ARCTIC REGIONS

Arctic oil spill response capabilities exist for a variety of spill situations where temperate open water response techniques, or techniques recently developed for cold regions, can be employed. Significant advances in the state-of-the-art of oil spill surveillance, containment, recovery, transfer, storage, and disposal have been made in recent years for temperate open water conditions. Much of this capability, however, is not applicable to arctic regions where low temperatures and the presence of ice complicate the oil spill response effort. Recognizing the inadequacies of cold region oil spill response capabilities, both industry and government have directed significant efforts toward upgrading these capabilities. The recently developed cold region oil spill response techniques, combined with certain temperate water oil spill response techniques, may be readily applied to many of the spill situations which could occur along the Alaskan coast as discussed in Volume I of this report.

The oil spill scenarios selected as the basis for this study addressed open water, solid shorefast ice, and broken ice conditions. It was concluded that many of the oil spill response techniques, and much of the hardware, developed for use in warmer climates can be used in combating oil spills in open water conditions in Alaska. Modifications to open water systems must be made, however, in consideration of the low temperatures, and the logistic requirements for transporting, deploying, and operating the equipment in the remote areas of the arctic. It has been generally recognized that some response capability for oil spills on or under solid shorefast ice exists through in situ burning of the oil. This type of response is aided by the use of heavy construction equipment which greatly reduces manpower requirements, allows personnel to work out of the cold in an enclosed cab, and permits the handling of large masses of contaminated snow and ice. It appears that the most difficult spill situation occurs when oil is spilled in broken ice cover having concentrations greater than 40%. In this type of situation, the recovery of oil intermixed with large ice floes could be difficult and hazardous with present technology. It is generally agreed that conventional oil recovery devices may be used in light broken ice fields. However, their usefulness can still be limited by large ice pieces, high oil viscosity and low ambient temperatures.

In order to identify equipment judged suitable for use in the spill response scenarios described in Volume I of the report, a survey of existing equipment was taken and an evaluation was made of the suitability of the equipment and techniques for use in coastal and offshore Alaskan conditions. The subsystems of the oil spill response system identified for this survey were surveillance, containment, recovery, transfer, storage, and disposal. The survey was accomplished by reviewing the state-of-the-art of these subsystems, and by evaluating the equipment and techniques for application in aquatic

cold regions oil spill response. A similar survey of spill response equipment was performed by ARCTEC, Incorporated for the Environmental Protection Agency through the University of Alaska in September of 1976. The information gathered at that time was used as the foundation for this survey and updated to January 1978 to include the more recent spill abatement developments. The evaluation of cold region oil spill response capability did not include testing of any kind. It was based on information contained in the technical literature, communications with experts in the field, and the experience of ARCTEC's staff. The following paragraphs describe the state-of-the-art for each subsystem, and the evaluation of subsystem capability in terms of applicability to cold regions. Recent developments in spill abatement technology which are specifically related to cold regions are also discussed in this Appendix.

Surveillance

Surveillance techniques can be used for detecting, mapping the areal extent, and locating concentrations of oil spilled in arctic regions. Most remote sensing devices can be used only in certain environmental conditions. For temperate open water surveillance, limitations include the amount of light available, sea state, cloud cover, oil type, and observation angle. In the arctic regions, interaction of spilled oil with ice and snow greatly intensify the spill surveillance problem. An oil slick can flow under ice, sandwich within growing ice, mix with snow, spread between ice floes, or intermingle with hummocks, ridges, and rafts. In addition, other natural and man-related optical phenomenon further complicate the oil detection and monitoring problem. These include periods of prolonged darkness, blowing snow, terrestrial refraction or mirages, optical haze, whiteout, snow blindness, steam fog, and ice fog.

These environmental conditions must be considered when evaluating oil spill surveillance techniques for use in cold regions. The primary problem in evaluating the application of current surveillance techniques for cold regions is that little experience in operating oil spill surveillance devices in arctic conditions has been acquired. The few tests reported include only the use of visual detection, photography, infrared imagery, impulse radar, and fluorescense detection. Since field experience is limited, the only means for evaluating these devices is on the basis of their operating principle.

The vast majority of current and proposed surveillance systems use some part of the electromagnetic spectrum for detection. Table B-1 is a summary of electromagnetic sensing devices which includes a discussion of their capability and an evaluation of their potential for successful application in the coastal and offshore areas of Alaska. As a matter of convenience in classifying these devices, they are described in the order of the wavelength of energy they use, with the shortest wavelengths listed first. The operating spectral band is given in the first column. The next column lists the individual surveillance techniques. The capabilities and limitations of the sensing techniques are discussed in the third column. Each system's potential for use over open water and for detecting oil spilled in various ice conditions is summarized in the last column.

TABLE B-1 SUMMARY OF ELECTROMAGNETIC SENSING TECHNIQUES

Spectral Band	Technique	Capability	Application in Offshore Alaska
UV	UV Linescanner	Requires good lighting and clear sky; severely limited by weather, even light haze or high humidity; false contacts on objects such as seaweed or thin films of fish oil.	Open water daylight, may respond to oil-on-ice with no snow but no tests recorded; gives real-time display plus permanent photo record
Visible	Human eye	Visibility depends on oil film thickness, sea state, color of water, sky conditions, angle of observation; visibility limited by darkness and obstructions such as haze, rain or fog	Primary means of detection at the drill site; oil can be detected in open water, ice-infested waters, oil-on-ice, in depressions in ice as limited by darkness and obstructions to visibility; visual detection may not be possible for oil mixed in snow, oil absorbed in ice, or oil under ice
	TV	Detectability depends on thickness of slick, daylight, obstructions to vision, and sea state	Same general conditions as for visual detection noted above
	L^3 TV	Close-range high-resolution slick observation; extends visual detection to lower lighting conditions; less effective in higher sea states	Daylight and twilight detection on open water, possible application in ice-infested waters, and some capability for oil on ice or snow: real-time display
	Wide Range Image Spectrometer	Can detect thin films of oil, limited to daylight and clear sky, calm sea	Open water, daylight; may sense oil on ice but no tests recorded

TABLE B-1 SUMMARY OF ELECTROMAGNETIC SENSING TECHNIQUES (Continued)

Spectral Band	Technique	Capability	Application in Offshore Alaska
Visible	Color Photography	Can map oil slicks showing difference between oil film and adjacent open water; limited to daylight, good visibility, favorable sun and observation angle, sky color and water color	Open water, good visibility; no recorded tests for ice infested waters or oil-on-ice; detection occurs with post flight processing of film
	Fraunhofer Line Discriminator	Monitors solar stimulated fluorescence; limited to clear sunny days; narrow sweep width therefore many sweeps required to map slick	Open water, daylight and good visibility; no recorded applications for ice infested waters or oil-on-ice; real-time processor
	Laser Fluorosensor	Potential for detecting oil spilled on water; determining oil type and slick thickness.	No reports of operational tests discovered to date
IR	Infrared Photography	Primarily an energy detector, performs better than normal photography in hazy conditions; limited to daylight with fairly clear skies	Daylight, clear weather open water, possible application for ice infested water and oil on ice or snow; detection post flight with film processing
	Infrared Color Photography	Slightly better contrast than black and white infrared; limited to fair weather and daylight	Same as for infrared photography
	Thermal Infrared Line Scanner (TIRLS)	Detects thermal differences between oil and water; effective in darkness and haze, will not penetrate rain or clouds; local thermal structure can cause false alarms; will not detect thin oil films	Day or night, haze, some capability in fog; open water, possible application in ice infested water; partially effective for oil-on-ice or snow; real-time display

TABLE B-1 SUMMARY OF ELECTROMAGNETIC SENSING TECHNIQUES (Continued)

Spectral Band	Technique	Capability	Application in Offshore Alaska
IR	Forward Looking Infrared (FLIR)	Same as TIRLS except provides a real-time TV type display	Effective in open water, ice-infested water, or possibly effective for oil-on-ice or snow; operator steerable line-of-sight, medium range detection; currently installed on most U.S. Navy patrol aircraft
Microwave	Passive Microwave Imager (PMI)	Day/night capability in haze and fog, partially effective in clouds, rain and snow; effective in rough seas and calm seas, may lose effectiveness in some combinations of oil film thickness and moderate seas; lim[illegible]ns include relatively course [illegible]solution and limited sweep w[illegible]	Open water; possibly effective in ice-infested waters; can estimate thickness of slick; TV display and video tape recording
	Active Microwave Imaging	Day/night capability; [illegible] effectiveness in high sea states and precipitation	[illegible] water, has potential for use in ice[illegible]fested waters
	Side Looking Airborne Radar (SLAR)	Day/night capability, clouds, and fog; adversely affected by heavy precipitation; subject to false alarm by wave-dampening effect of fish oil or brash and grease ice; thin oil films easily detected	Open [illegible] time CRT display of large areas [illegible]derate ranges; likely to have difficulty in ice-infested waters.

TABLE B-1 SUMMARY OF ELECTROMAGNETIC SENSING TECHNIQUES (Continued)

Spectral Band	Technique	Capability	Application in Offshore Alaska
Microwave	Probing Radar	Can penetrate through surfaces. Still in developmental stage, has a limited sweep width	Has potential for detecting oil under ice
Multi-spectral	Multispectral Photography	Daylight, clear weather only	Open water, no reports of u[illegible] in ice-infested waters
	Multispectral Optical Mechanical Scanners	Can search for the spectral band or combination of bands showing greatest constrast; limited by day-light and weather	Open water, no report[illegible] in ice-infested waters
	Intensified Optical Multi-Channel Analyzers	Effective in very low (starlight level) illumination; affected by obstructions to visibility	Open water, n[illegible]orts of use ice-infested waters

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Sensing techniques and devices which do not use spectral bands are summarized in Table B-2. Included are gas analyzers, oil detectors, manual techniques, and the use of divers.

The lack of an empirical data base upon which to evaluate remote sensing devices for application in cold regions limits the possible depth of this analysis. The Canadian Environmental Protection Service is planning a field evaluation of remote sensors for detecting oil in brash ice, slush ice, and between ice floes. These tests are planned for August 1978. Nearly all of the electromagnetic sensing techniques described in Table B-1 will be evaluated during this test program. The Canadians are also planning to conduct tests in December of 1978 for detecting oil underneath solid ice using remote sensors. Again, various techniques will be evaluated under field conditions.

In summary, there currently exists adequate capability for remote sensing of oil spilled on open water. Oil spilled on top of ice can be surveyed by visual detection, which may be improved by L^3TV, TIRLS, FLIR, microwave imaging, and multispectral techniques. Gas analyzers may be effective for surveillance depending on the volatility of the oil. These devices also show some potential for detecting oil spills in broken ice conditions; however, current devices are least effective for the surveillance of oil spilled underneath ice, sandwiched within solid ice, or completely covered by snow. Devices which appear to offer some potential for penetrating ice and snow include impulse radars, impulse laser fluorosensors, and microwave detection. The present state-of-the-art for under-ice detection is limited to the use of divers, drills, and augers.

Containment

A wide variety of containment barriers are commercially available for use in open water conditions. The usual limitations in containing spilled oil in open water are winds, waves, and currents. For example, a water current velocity of about 0.6 kts normal to the boom is usually considered to be the upper limit for successful retention of oil by the boom. In the arctic, the usefulness of many booms is further limited by the additional environmental conditions of low temperature, stable ice cover, broken ice fields, moving ice floes, and snow. However, it has been judged that some commercial containment equipment and techniques can be applied to some limited extent in the arctic.

The following paragraphs provide an evaluation of commercial containment booms for use in broken ice and a discussion of oil barriers specifically designed for use in the arctic environment.

Commercial Containment Booms

The most comprehensive testing of commercial oil containment booms in cold regions was performed by the U.S. Coast Guard as part of their Arctic Pollution Response Program. Field tests were conducted in Kachemak Bay, located near Homer Alaska, during November and December of 1973. Ten commercial oil containment barriers were evaluated in broken ice and cold temperatures. The results are summarized as follows:

TABLE B-2 SUMMARY OF NON-SPECTRAL DETECTION

Technique	Capability	Application in Offshore Alaska
Gas Analyzer	Detect petroleum vapors; exhaust gases of vehicles can cause false alarms; can monitor at a fixed position, or can be hand-held or mounted in an aircraft	Can detect oil vapors in open water in ice-infested waters, or through cracks in ice
Oil Detector	Moored buoy detects presence of oil in water; does not respond to high viscosity oils; warning signal transmitted on VHF to monitor receiver	Open water
Manual	Auger a hole in the ice; slow, labor intensive operation; generally observations limited to small number of isolated points	Shorefast ice
Divers	Detect oil under ice	Shorefast ice

1. Barriers having smooth sides are capable of deflecting ice floes.

2. Barriers without smooth sides, that is, having projecting flotation elements or bridles to external tension lines, are subject to abrasion damage from ice interaction while deflecting ice floes.

3. When deployed perpendicular to the direction of ice flow in a U-shaped configuration, barriers having integral tension members fail when ice loads reach a certain level by rotating out of the water, up, and onto the ice. While the oil containment fails in such an action, as far as the boom itself is concerned, the mechanism is a fail-safe one in that the barrier relieves itself of high ice loads before these loads cause a parting of the barrier itself.

4. Barriers with external tension lines will contain floating ice without riding up onto the ice. However, since these barriers do not relieve themselves as ice loads increase, they will eventually be subject either to structural failure, or to mooring system failure.

5. Hardware used to connect barrier sections and to connect the barrier end plates for towing or mooring must provide for quick positive connection or attachment by a person wearing heavy gloves or mittens.

As shown by these field investigations, broken ice and cold temperatures present special oil containment problems. Some boom designs tend to operate more effectively than others under these conditions. Therefore, in evaluating booms for use in broken ice and cold temperatures, several boom construction features are desirable. These features include smooth sides, non inflatable buoyancy members in view of the possibility of ice puncture, tension members integral to the boom, strength suitable to withstand some ice loads, connectors easy to manipulate with gloves and additional reserve buoyancy because of the potential loss of boom flotation due to icing.

For the purpose of this evaluation, ARCTEC, Incorporated has chosen to separate commercial oil containment booms into three categories according to their general strength or ruggedness. These categories are light, medium, and heavy duty. While attempts were made to make the survey as comprehensive as possible, it is likely that there are some commercially available booms which have not been evaluated in this study because they are not well known or have limited distribution. The booms are summarized in Tables B-3, B-4, and B-5. Listed in the tables are the manufacturers, the boom names, a brief description of each boom, and major boom specifications and characteristics. The final column of each table contains comments on the estimated usefulness of these booms in broken ice conditions.

In reviewing the information summarized in Table B-3 for light duty containment booms, three booms are judged as having potential for use in skim ice conditions. Of the medium duty containment booms listed in Table B-4, six are considered suitable in light brash ice conditions. None of these,

however, are suitable for use in moving fields of ice. One of the heavy duty booms summarized in Table B-5 is judged suitable for use in the presence of small broken ice pieces.

Oil Barriers for Arctic Use

Aside from these commercial containment booms, a review and evaluation of special containment techniques specifically intended for use in ice conditions was also completed. These devices and techniques are briefly discussed in the following paragraphs.

The ice-oil boom, which is a combination of a perforated ice boom and an oil containment boom, shows some promise for use in broken ice. The perforated boom is designed to pass oil through while not allowing passage of large ice pieces. The ice boom therefore deflects ice away from the oil containment boom. The oil containment boom then concentrates the oil and oil-coated small ice pieces which pass through the ice boom for recovery.

A device developed by Canadian Marine Drilling, Ltd. and Bennett Pollution Controls, Ltd. called the Arctic Boom, also offers some potential for use in broken ice conditions. The boom was designed to survive high tension loads. The smooth sides minimize ice snag, and the flotation members are protected from ice puncture. Field tests have been completed, but the results are not yet publically available.

Another boom developed by Bennett called the Deep Skirted Boom has potential application in solid shorefast ice conditions. This boom is installed through a slot cut in the shorefast ice. The 12 ft deep containment skirt is capable of containing a considerable amount of oil providing there are no significant water currents present.

Trenching the ice also can serve as an effective containment technique. Trenches can divert the oil and concentrate it in the ice slot. This technique can also be used to expose oil that is spilled under the ice to the surface. This technique may be limited when temperatures are extremely low due to the refreezing of the slot.

An ice keel can also serve as an effective containment barrier for oil flowing underneath ice. Ice keels can be constructed by pumping water onto the ice surface. Ice keels can also be formed by removing the insulating cover of snow from the ice surface thereby causing more rapid ice growth.

Another concept is to create a containment pocket in the ice by insulating it by the use of snow or special insulating material. This will locally limit the ice growth and encourage a pocket to form underneath the ice. Oil spreading underneath the ice will pool in this pocket.

Other alternatives for containment are net and bubble barriers which could be used to partially contain oil even in the presence of broken moving ice fields. These concepts are particularly useful during a continuous oil release such as in the case of a blowout. These concepts are being further investigated by the Canadian Environmental Protection Service.

TABLE B-3 SUMMARY OF LIGHT DUTY CONTAINMENT BOOMS

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Acme Products Co. P.O. Box 51388 Tulsa, Oklahoma 74151	Acme O.K. Corral	Flexible foam flotation wrapped in flexible skirt material of vinyl impregnated nylon fabric with chain ballast	4,6,8, 10,12	6 to 12	1.5 for 18 in	360	Fabric	Quick-Latch	Smooth	50 to 300	-40	Probably inadequate in light brash ice
American Marine, Inc. 401 Shearer Blvd. Cocoa, Florida 32922	Simplex	Flexible foam flotation wrapped in skirt of flexible nylon reinforced vinyl fabric with chain ballast	6	12,18, 24	2	300 or 400 fabric, to 5300 lb chain	Fabric and chain	Quick	Smooth	50 to 100	0	Probably inadequate in light brash ice
Bennett Pollution Controls, Ltd. 119 Charles St. N. Vancouver, B.C. Canada	Inshore	Flat flexible foam flotation wrapped in skirt of flexible vinyl coated nylon with lower or upper and lower 1/4 in. steel cables	5,6,8	7,12	1.8	7000 lb or 14000 lb	Fabric and cable	Slide & pin	Very Smooth	50	NA	Likely applicable in skim ice; flat flotation provides very smooth surface.
Bennett Pollution Controls, Ltd. 119 Charles St. N.Vancouver, B.C. Canada	Navy	Rigid polyethylene foam flotation wrapped in flexible vinyl coated nylon with bottom steel cable	5,8	8	NA	NA	Fabric and cable	Slide & pin	Smooth	50	NA	Likely applicable in light skim ice.
Coastal Services 22 River Street Braintree, Mass. 02184	Coastal	Flexible nylon reinforced vinyl fabric with external rigid foam flotation, external load cables & external chain ballast.	6,12	12,24	1.65, 2.35	260	Cable and Fabric	Snap hooks	Projections	50,100	-65	External flotation unlikely to survive extended interaction with broken ice pieces
Colloid Spilldam, Inc. P.O. Box 861 Brockton, Mass. 02403	Spilldam-150	Vinyl coated nylon fabric with flat internal rigid polyethylene flotation, two enclosed 1/4 in polypropylene tension lines, and lead ballast	6	9	1.25	500 fabric	Rope & fabric	Snap hooks	Very smooth	100	-65	Probably is inadequate in light brash ice

TABLE B-3 SUMMARY OF LIGHT DUTY CONTAINMENT BOOMS (Continued)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Colloid Spilldam, Inc. P.O. Box 861 Brockton, Mass. 02403	Spilldam 180&360	Vinyl coated nylon fabric with cylindrical externally attached polyethylene floats, two enclosed polypropylene tension lines and external chain ballast	11	7	2.	500 fabric	Rope & fabric	Snap hooks	Projections	100	-65	External flotation unlikely to survive extended interaction with broken ice pieces
Effluent Mgmt. Company 250 Earls Court Rd. London SW5 9AD England	Skimmex	Flexible reinforced vinyl fabric with individual 15 ft. long inflation chambers	5,12	6,13	0.8, 1.25, 2.5	NA	Fabric	Turnbuckles	Smooth	12	NA	Air-inflated flotation chambers unlikely to survice extended interaction with broken ice pieces
Environetics, Incorporated 5934 West 116 Place Worth, Illinois 60482	Boa-Boom	Flexible nylon reinforced vinyl fabric with either air-inflatable bladder flotation or polyfoam filled vinyl bladder flotation and chain ballast	9	18	1.25, 2.0	200	Fabric	Vinyl zipper	Smooth	10, 25	-20	Air-inflated model unlikely to survive extended interaction with broken ice pieces; foam flotation model likely applicable in skim ice
Gamlen Chemical Co. 299 Market St. Saddle Brook, NJ 07662	Gamlen Boom	Aluminum/magnesium alloy vertical plates with rigid alloy box flotation on each side connected with reinforced asbestos panels	6,8	12	2.2	6000, 10000, 14000 lbs	Plates & chain	Eyelets & fasteners	Projections	16.4	NA	Flotation boxes subject to ice damage; plates and flotation boxes likely to ice up
Goodyear Aerospace Corp. Engineered Fabrics Div. Rockmart, Georgia 30153	Sea Sentry	Flexible rubber impregnated nylon fabric with air-inflated flotation chambers, chain tension members and chain ballast	9	18	5	5100 and 10200 lb 600 lb/in fabric	Chain	Bolts in grommets	Smooth	68,55	-30	Connection may be difficult at low temperatures
Gundry Bilimac Ltd. 996 Powell Street Vancouver, B.C. Canada	King-Fish	Flexible nylon fabric with P.V.C. flotation members, 5/8" tow line center of float with a lead-weighted cable at bottom for ballast	5-1/2	13-1/2	0.88	NA	5/8" tow line	NA	Smooth	200	NA	Unlikely to survive interaction with broken ice
Hoyle Marine Ltd. 24 Elm Park Road Wallasey, Cheshire, England	Hoyle	Rigid foam filled G.R.P. flotation panels with vinyl coated polyester fabric skirt	3	9	NA	NA	Fabric	Quick-connect plates	Projections	NA	NA	Four foot long floats alternating with one foot spaces would impair smooth movement of ice along the surface

TABLE B-3 SUMMARY OF LIGHT DUTY CONTAINMENT BOOMS (Continued)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Hurum Enterprises, Inc. 87 Main Street Champlain, NY 12910	Flexy-Lite	Polyolefin fabric curtain with chain tension members, chain ballast, and external flotation cylinders of hollow plastic or ethafoam (optional)	6,8 12	12,16 24	2	200 fabric	Chain	Slide clamps	Projec-tions	50	-20	External flotation unlikely to survive extended interaction with broken ice pieces
JPS Equipment Inc P.O. Box 13095 Port Everglades, Fla. 33316	R-Type	Nylon reinforced vinyl curtain with fiberglass verti-cal supports, en-closed rigid flat polyethylene foam flotation and top and bottom poly-propylene rope tension lines, lead ballast	6	10	1.1	2500 lb rope 500 fabric	Ropes	Snap hooks	Very smooth	100	-65	Likely applicable in light brash ice
Kepner Plastics Fabricators, Inc. 4221 Spencer Street Torrance, Calif. 90503	Sea Curtain	Flexible vinyl coated nylon fabric with enclosed plas-tic foam flotation and steel cable or chain tension line	4,5,7	9,11	1.0	450 fabric	Cable or chain	Eyebolts & wing-nuts	Very smooth	100	-65	Likely applicable in light skim ice; connection may be cumbersome at low temperatures.
Logan Diving Inc. 5731 St. Augustine Road Jacksonville, Fla. 32207	Flo-Fence	Plastic coated glass fiber curtain with cylindrical flotation elements, cable ballast and rope tension line	4	8	0.95	NA	Rope	None	Smooth	50 to 200	-10	Unlikely to survive interaction with broken ice
Marsan Corporation Box 83, Route 1 Elgin, Illinois 60120	Type I and II	Flexible vinyl im-pregnated nylon fabric enclosing rigid flat urethane foam flotation and chain ballast	8	12	1.97	300 fabric	Fabric	Grommet holes and wingnuts	Very smooth	50	-30	Rigid foam flotation and connection type may make handling cumbersome at low temperatures
Megator Corporation 136 Gamma Drive Pittsburgh, PA 15238	Mini-Boom	Vinyl coated nylon cloth with enclosed rigid polyurethane foam floats, nylon rope tension member and mild steel ballast	2	7	0.64	NA	Rope	Lashed through eyelets	Smooth	16.5	NA	Unlikely to survive interaction with broken ice

TABLE B-3 SUMMARY OF LIGHT DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Pollution Recovery 1310 Old River Rd. Cleveland, OH 44113	Samsil	Flexible PVC coated material, 4" diameter flotation made of Dow Etha Foam with flexible steel wire rope as ballast	6	14	1.4	5,000 towing strap	2" nylon	NA	Bumps	150	-40	Probably not applicable in light ice
Reynolds International, Inc. Box 27002 Richmond, VA 23261	Aluminium	Corrugated aluminium sheet with flat acrylonitrile closed cell foam flotation and round aluminum bar stock ballast	5,7	10,21	1.0	NA	Fabric	Three bolts	Very smooth	100	-30	Likely applicable in skim ice; making connections could be cumbersome at low temperatures
Skandinavisk Oljeservice AB St. Budhusgatan 20 411 21 Goteborg, Sweden	SOS Flema	Flexible nylon reinforced tubes, upper tube filled with air, lower with water; two polyester tension lines	15.7	17.7	1.4	336 fabric 6600 lb line	Rope	Four Bolts	Smooth	82	-5	Ice damage to air filled tube would result in loss of flotation; connection could be difficult to make at low temperatures
Skandinavisk Oljeservice AB St. Budhusgatan 20 411 21 Goteborg, Sweden	SOS	Flexible nylon reinforced vinyl curtain with either air tube or plastic balls flotation and chain ballast	7.9	15.7	1.07	336 fabric	Chain	Slide	Smooth	83	-5	Ice damage to flotation enclosures could result in loss of flotation
Slickbar, Inc. P.O. Box 139 Southport, Ct. 06490	Mark VI	Flexible vinyl impregnated ployester fabric with external semi-cylindrical rigid polyethylene foam flotation, 1/4 in. SS cable tension line and lead ballast	4,6.5	6,8	0.89	500 fabric	Cable	Pin	Projections	50 to 200	-20	External flotation unlikely to survive extended interaction with broken ice pieces
Trellegorg Rubber Company, Inc. 30700 Solon Industrial Pkwy. Solon, Ohio 44139	Red Eel	Two-ply PVC film enclosing triangular styrofoam flotation, polypropylene tension line and sand bag ballast	8	15,5	2.68	NA	Rope	Tied	Bumps	164	-20	Unlikely to survive interaction with broken ice

TABLE B-3 SUMMARY OF LIGHT DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Uniroyal, Inc. 312 North Hill St. Mishawaka, Indiana 46544	Seald-boom	Flexible Paracril-Ozo coated fabric enclosing rigid trapezoidal closed cell Ensolite foam flotation each side with lead ballast	6	12	1.5	500 to 600 fabric	Fabric	Bolted grommets	Bumps	40	-20	Segmented flotation could present ice interaction problems; handling and assembly could be cumbersome at low temperatures due to rigid flotation and bolted grommets
Whittaker Corp 5159 Baltimore Dr. La Mesa, Calif. 92041	Expandi	Flexible nylon reinforced curtain enclosing a spring loaded silf-inflating flotation chamber and chain tension line and ballast	11	18.5	1.6	5,700 lb and 16,500 lb chain	Chain	Slide	Very smooth	82,50	NA	Air inflated flotation chambers unlikely to survive extended interaction with broken ice pieces.

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Amercian Marine Incorporated 401 Shearer Blvd. Cocoa, Fla. 32922	Super-max	Solid polystyrene flotation wrapped in flexible skirt of nylon reinforced vinyl with 5/8 in. diameter steel cable in bottom	12	24	3.5	35,000 lb cable, 21,000 lb fabric	Bottom cable and fabric	Quick	Smooth	50	0	Likely applicable in moderate broken ice fields
American Marine, Incorporated 401 Shearer Blvd. Cocoa, Florida 32922	Optimax	As above with additional top tension member of steel cable	7	12,18, 24	2.5	300 or 400 fabric, 9800 lb cable, 5300 lb chain	Fabric, chain, cable	Quick	Smooth	50 to 100	0	Probably inadequate in light brash ice
Bennett Pollution Controls, Ltd. 119 Charles St. N. Vancouver, B.C. Canada	Inshore	Flat flexible foam flotation wrapped in skirt of flexible vinyl coated nylon with lower or upper and lower 1/4 in. steel cables	12	16,24	3.0	7000 lb or 14000 lb	Fabric and cable	Slide & pin	Very smooth	50	NA	Likely applicable in light brash ice; flat flotation provides very smooth surface
Bennett Pollution Controls, Ltd. 119 Charles St. N. Vancouver, B.C. Canada	Navy	Rigid polyethylene foam flotation wrapped in flexible vinyl coated nylon with bottom steel cable	12	16,24	NA	NA	Fabric and cable	Slide & pin	Smooth	50	NA	Likely applicable in light brash ice
Bennett Pollution Controls, Ltd. 119 Charles St. N.Vancouver, B.C. Canada	River	Round flexible foam flotation wrapped in flexible vinyl coated nylon with bottom steel cable	6	12	2.75	14000 lb	Fabric and cable	Slide & pin	Smooth	50	NA	Likely applicable in light brash ice
B. F. Goodrich Engineering Systems Co. 430 South Main St. Cohasset, MA 02025	Sea	1/4" vinyl sheet skirt with rigid eliptical internal flotation made of Searethane internal ballasting	6,12	12,24	8-12	6000-10000	None	NA	Projections	23.5	NA	The flotation member sticks out in an eliptical shape along the water surface not allowing ice to pass. Also, it has no tension members.

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/ft	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
BP North America, Inc. 620 Fifth Avenue New York, NY 10020	Vicoma Seaboom	Three tube configuration of flexible butachlor coated nylon fabric, upper tubes inflated with air, bottom tube with water	30	17	3	5500 lb	Fabric	NA	Very smooth	1600	-32	Tested for flexibility to -50°F; continuous surface desirable, not recommended for use in broken ice due to possibility of puncture of air or water tubes
Clean Water, Inc. P.O. Box 1002 Toms River, NJ 08753	Harbour	Rigid foam flotation wrapped in nylon reinforced vinyl skirt with 1/2 in. polypropylene line tension member and chain ballast	8	24	NA	NA	Rope & fabric	Universal Fasteners	Very smooth	50	NA	Likely applicable in light brash ice; fasteners may be hard to work with at low temperatures
Colloid Spilldam, Inc. P.O. Box 861 Brockton, Mass. 02403	Spilldam 180 & 360	Vinyl coated nylon fabric with cylindrical externally attached polyethylene tension lines, and external chain ballast	12	24	3	500 fabric	Rope & fabric	Snap hooks	Projections	100	-65	External flotation unlikely to survive extended interaction with broken ice pieces
Gamlen Chemical Co. 299 Market St. Saddle Brook, NJ 07662	Gamlen Boom	Aluminum/magnesium alloy vertical plates with rigid alloy box flotation on each side connected with reinforced asbestos panels	10	12,24	4,3	6000, 10000, 14000 lbs	Plates & chains	Eyelets & Fasteners	Projections	16.4	NA	Flotation boxes subject to ice damage; plates and flotation boxes likely to ice up
Goodyear Aeorspace Corp. Engineered Fabrics Div. Rockmart, Georgia 30153	Sea Sentry	Flexible rubber impregnated nylon fabric with air-inflated flotation chambers, chain tension members and chain ballast	12	24	10	5100 and 10200 lb 600 lb/in fabric	Chain	Bolts in Grommets	Smooth	68,55	-30	Connection may be difficult at low temperatures
Hurum Enterprises, Inc. 87 Main Street Champlain, NY 12919	Standard	Vinyl impregnated nylon fabric with integral flexible foam flotation, 1/4 in steel cable tension lines top and bottom, and lead ballast on bottom cable	12	24	3	400 fabric	Cables	Slide clamps	Smooth	50	-45	Limited to very light brash ice

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
JPS Equipment Inc. P.O. Box 13095 Port Everglades, Florida 33316	Heavy duty	Nylon reinforced curtain with external cylindrical rigid foam flotation and 5/16 chain bottom tension line	12	24	2.35	500 fabric	Chain	Snap Hooks	Projections	100	-65	External flotation unlikely to survive extended interaction with broken ice pieces
Kepner Plastics Fabricators, Inc. 4221 Spencer Stree Torrance, Calif. 90503	Sea Curtain	Flexible vinyl coated nylon fabric with enclosed plastic foam flotation and steel cable or chain tension line	9,11 13	13,17 21	6.0	450 fabric	Cable or Chain	Eyebolts & Wing-nuts	Very Smooth	100	-65	Likely applicable in light brash ice; connection may be cumbersome at low temperatures.
Kleber-Colombes 6 Avenue Kleber Paris 16, France	Acorn	Flexible elastomer covered nylon fabric enclosing cylindrical flotation of Styropor beads and a chain ballast and fabric tension lines	12	20	10	NA	Chain & Webs	Cylinder, webbing, and chain connect separately	Very smooth	16,33	NA	Puncture of fabric by ice could result in release of flotation beads; multi-component connections could be cumbersome at low temperatures.
Kleber-Colombes 6 Avenue Kleber Paris 16, France	Balaer	Flexible elastomer covered nylon fabric with either spring actuated air flotation pockets or Styropor filled cushion flotation, chain and web tension lines, chain ballast	10,15, 21	14,21, 30	3.4, 5.4, 7.7	NA	Chain & Web	Bolted tow plates	Bumps	33,82, 164	NA	Puncture of fabric by ice could result in loss of flotation; uneven surface unlikely to survive extended interaction with broken ice pieces.
Marsan Corporation Box 83, Route 1 Elgin, Illinois 60120	Type I and II	Flexible vinyl impregnated nylon fabric enclosing rigid flat urethane foam flotation and chain ballast	16	24	4.0	300 fabric	Fabric	Grommet holes and wingnuts	Very smooth	50	-30	Rigid foam flotation and connection type may make handling cumbersome at low temperatures.
Metropolitan Petroleum Petrochemicals Co, Inc. 25 Craven Point Rd. Jersey City, NJ 07305	MP Boom	Flexible vinyl coated nylon fabric enclosing polystyrene foam beads in a vinyl buoyancy chamber with high density PVC ballast and stainless steel cable tension line	6	12	2.2	NA	Cable	Plate and shackles	Smooth	100	-30	Ice damage to enclosures of flotation beads could conceivably result in release of the beads and loss of flotation.

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Oil Spill Control Systems 401 McCormick San Leandro, Calif. 94577	Oilfence	Polyurethane impregnated woven synthetic fabric with permanently attached swivel mounted outrigger flotation	9,12,18, 24	9,12, 18,24	4 to 15	1800 fabric	Fabric	Navy	Projections	100	NA	Outrigger flotation unlikely to survive extended interaction with broken ice pieces.
Pacific Pollution Control 420 Market Street San Francisco, Calif. 94111	Aquafence	Semi-flexible resin impregnated woven fabric with outrigger flotation both sides by closed cell polyurethane floats	6 to 48	6 to 48	2.7 to 25.1	NA	Fabric	Quick	Projections	100	-20	Outrigger flotation unlikely to survive extended interaction with broken ice pieces.
Pains-Wessex (Canada) P.O. Box 2971 Postal Station D Ottawa, Ontario Canada	Bridgestone	Rubber with pleated skirt, air flotation, rope as the tension member, and lead weights as ballast	12-16	20-24	7-10	NA	Rope	NA	Bumps	65.5	NA	Air flotation is likely to be punctured by ice.
Parker Systems, Inc. P.O. Box 1652 Norfolk, Va. 23501	PSI	Flexible vinyl coated nylon fabric enclosing cylindrical flexible foam flotation and 1/4 in. coil chain ballast and tension line	6	12	2	300 fabric, 10000 chain & fabric	Chain and fabric	Hook and ring	Smooth	50 or 100	-20	Probably not applicable in light brash ice
A.G. Peterson & Sons, Inc. 491 West Main St. Avon, Mass. 02322	Slickguard	Flexible vinyl impregnated nylon fabric with enclosed semi-cylindrical foam flotation each side, lead ballast, and 3/16 in. stainless steel cable tension line	12	24	3	400 fabric	Cable	Pins	Smooth	50	-50	Likely applicable in light brash ice; connections may be cumbersome

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Quincy Adams Marine Basin, Inc. 47 Palmer Street Quincy, Mass. 02619	Standard	Semi-rigid polypropylene sheet with rectangular wood flotation and lead ballast	6,12,18	18,24, 30	4 and over	NA	Fabric	Brass hinges and pins	Projections	10	NA	Likely to be cumbersome to handle at low temperatures and curtain may fail at low temperatures
AB Sjuntorp S-460 20 Sjuntorp Sjuntor, Sweden	Sjuntorp	Flexible nylon yarn coated with synthetic rubber. Flotation is from inflated chambers with lead ballasts	11-3/4 to 28-1/2	16-1/4 to 39-1/2	2.7 to 5.4	NA	Ropes	Coupling bars	Projections	NA	NA	The damage to air flotation chambers could result in loss of flotation
Skandinavisk Oljeservice AB St. Budhusgatan 20 411 21 Goteborg, Sweden	SOS Perma-	Flexible nylon reinforced vinyl curtain in Y section with rigid flotation tubes or discs shackled in the Y with lead or chain ballast and cable tension member	7.9, 15.7	15.7 to 29.5	2 to 10	6600 to 17200 lb	Cable	NA	Smooth	To order	NA	Likely applicable in light brash ice
Slickbar, Inc. P.O. Box 139 Southport, Ct. 06490	Mark V	Flexible vinyl impregnated polyester fabric with external cruciform shaped rigid polyurethane foam flotation, 3/8 in. SS cable tension line and lead ballast	12	24	NA	500 fabric 10,000 lb cable	Cable	Pin	Projections	to 500	-40	External flotation unlikely to survive extended interaction with broken ice pieces.
Slickbar, Inc. P.O. Box 139 Southport, Ct. 06490	Mark VI	Flexible vinyl impregnated polyester fabric with external semi-cylindrical rigid polyethylene foam flotation, 1/4 in. SS cable tension line and lead ballast	6.5	10,12	4.06	500 fabric	Cable	Pin	Projections	50 to 200	-20	External flotation unlikely to survive extended interaction with broken ice pieces.

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Slickbar, Inc. P.O. Box 139 Southport, CT 06490	MK9	Flexible woven polyester fabric, PVC coated with polyethylene foam for floatation and riveted lead for ballast	5.5, 5.6	7,9, 11,13	2.5,2.8 3.4,3.9	340 for fabric	Cable	Pin	Projec-tions	60	-20	External floatation unlikely to survive extended interaction with broken ice pieces.
Submarine Engineering Assoc. Inc. 430 South Main St. Cohasset, Mass. 02025	Sea Boom	Flexible curtain of 1/4 in. rubber with external foam flotation and lead and sand ballast, or cylindrical ballasting tubes for submersible model intended for permanent installations	12	24	13 and 15	1800 to 2200 fabric	Fabric	Hinge pin	Smooth	24	-48	Foam flotation model likely applicable in light brash ice; air chamber flotation model, recommended only for fixed in-stallation by manu-facturer, subject to potential puncture of buoyancy chambers by ice.
Trelleborg Rubber Co., Inc. 30700 Solon Indus-trial Pkwy. Solon, Ohio 44139	Uni-versal	Flexible polyure-thane-impregnated nylon fabric with pocketed rectangu-lar styrofoam flo-tation and iron powder ballast, and a polypropylene tension line.	14	27	5	245 Fabric	Rope	Hank coupling	Bumps	115	-20	Unlikely to survive extended interaction with broken ice pieces.
Trygve Thune A/S Munchs gate 5 Oslo 1, Norway	T-T Super	Flexible vinyl coated nylon curtain with two terylene lines and a chain tension member, external rigid foam flotation and lead ballast	12	24	2.7	300 Fabric	Chain	Slide	Project-ions	164	NA	External flotation unlikely to survive extended interaction with broken ice pieces.
Uniroyal, Inc. 312 North Hill St. Mishawaka, Indiana 46544	Seald-boom	Flexible Paracril-Ozo coated fabric enclosing rigid trapezoidal closed cell Ensolite foam flotation each side with lead ballast	12,24	24,48	9.6	500 to 600 fabric	Fabric	Bolted grommets	Bumps	40	-20	Segmented flotation could present ice interaction problems; handling and assembly could be cumbersome at low temperatures due to rigid flotation and bolted grommets.

TABLE B-4 SUMMARY OF MEDIUM DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Underwater Technics Inc. 2735 Buren Avenue Camden, NJ 08105	Twin-Pull	Nylon reinforced PVC with 6" Etha foam flotation with 5/16" ballast chain.	8	18	NA	5,300 chain	Cable	Quick Discon-nect	Bumps	100	NA	Pulls both tension and ballast members at the same time cupping ice.
Whittaker Corp. 5159 Baltimore Dr. La Mesa, Calif. 92041	Expandi	Flexible nylon rein-forced curtain enclo-sing a spring loaded self-inflating flota-tion chamber and chain tension line and ballast	18	25.5	3.5	5,700 lb and 16,500 lb chain	Chain	Slide	Very Smooth	82,50	NA	Air inflated flotation chambers unlikely to sur-vive extended inter-action with broken ice pieces.
Willam Warne & Co., Ltd. Barking Essex, England	Types E,S, T8, T16	Flexible chloro-prene or neoprene coated terylene fabric with either air inflated or rigid foam flota-tion and chain ballast	6,13	15,20	3 to 10	115 to 250 fabric	Fabric	Hinge pin	Smooth	50	NA	Air inflated model unlikely to survive extended interaction with broken ice pieces; insufficient strength for use in ice and will be diffi-cult to connect at low temperatures

TABLE B-5 SUMMARY OF HEAVY DUTY CONTAINMENT BOOMS

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb or lb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Bennett Pollution Controls, Lts. 119 Charles St. N. Vancouver, B.C. Canada	Harbour	Semi-rigid neoprene covered polyester fabric with clipped and bolted urethane foam filled rigid polyethylene flotation chambers each side	10,12	14,18 24	7,8,9	30,000, 35,000 40,000 lbs	Fabric	Slide and pin	Projections	Optional	NA	Protruding flotation cells unlikely to survive extended interaction with broken ice pieces
Bennett Pollution Controls, Ltd. 119 Charles Street N. Vancouver, B.C. Canada	Off-shore	Top-half is PVC coated material and the bottom-half is semi-permeable, tension members are 1/4" cables at top, 3/4" cables inside skirt. Lead ballast	27	30	12	110,000	1/4 cables in top, 3/4 cables inside skirt at bottom	NA	Projections	Optional	-40	Protruding flotation cells unlikely to survive extended interaction with broken ice pieces.
B.F. Goodrich 430 South Main St. Cohasset, MA 02025	Seaboom Perma-float	Heavy duty geon vinyl, end plates are cast polyurethane stiffeners and pins are fiberglass reinforced plastic	12,18	24,36	12 to 70	10000 to 35000 lbs	Fabric	Pins	Eliptical	65 to 145	NA	Protruding flotation cells unlikely to survive extended interaction with broken ice pieces
Clean Water Inc. P.O. Box 1002 Toms River, NJ 08753	Off-shore	Flexible boom of nylon reinforced vinyl with individual 10 ft. long inflatable flotation chambers, chain or cable tension member and chain ballast	12	24	7.5	to 80,000 lbs	Chains or cables	Universal fasteners	Projections	55	30	Protruding air-inflated flotation chambers unlikely to survive extended interaction with broken ice pieces
Gamlen Chemical Company 299 Market St. Saddle Brook, NJ 07662	River Guard, Hi-Sea Guard	Flexible reinforced vinyl boom with enclosed narrow flexible foam flotation blocks, cast iron ballast; hi-sea model has air-trapping fabric pockets	15	25	6	22,000 and 55,000 lbs	Fabric	NA	Projections	165, 33	NA	Protruding air trapping pockets unlikely to survive interaction with broken ice pieces; without air pocket feature, likely applicable in moderate broken ice fields

TABLE B-5 SUMMARY OF HEAVY DUTY CONTAINMENT BOOMS (CONTINUED)

Manufacturer	Boom	Description	Freeboard in.	Draft in.	Weight lb/ft	Strength lb orlb/in	Tension Member	Connector	Active Face	Standard Length, ft	Minimum Temp, °F	Comments Related to Cold Regions
Goodyear Aerospace Corp. Engineered Fabrics Division Rockmart, Georgia 30153	Sea Sentry	Flexible heavy-duty nylon with nitrile-PVC coating, air-inflated flotation chambers, chain ballast and tension members	24	36	14.6	36,000 lbs 1200 lb/in fabric	Chains	Bolts in grommets	Smooth	98	-30	Air-inflated flotation chambers unlikely to survive extended interaction with broken ice pieces; connection may be difficult at low temperatures
Hurum Enterprises, Inc. 87 Main Street Champlain, NY 12919	Flexy High-Sea	Flexible vinyl impregnated nylon skirt with 3/8 in. steel cable tension lines top and bottom, 1/2 in. steel chain ballast, and external inflatable plastic sphere flotation	24	48	10	500 lb/in fabric	Cables	Bolt through eyelets	Projections	50	-45	External spherical floats unlikely to survive extended interaction with broken ice pieces; connection by bolting through eyelets would be cumbersome at low temperatures
Kepner Plastics Fabricators, Inc. 4221 Spencer St. Torrance, CA 90503	Sea Curtain	Flexible vinyl coated nylon fabric or polyethylene material with enclosed plastic foam flotation and steel cable and chain tension lines	23,26	36,42	18	450 lb/in fabric	Cables and chain	Eye-bolts and wing nuts	Very smooth	100	-65	Likely applicable in moderate broken ice fields; connection likely to be cumbersome at low temperatures
Offshore Devices Building 43 Summit Industrial Park Peabody, Mass.	High Seas Boom	Skirts made of nitrile PVC blend; external flotation members are air-inflated; ballast is by a strut clamped onto the skirt; in addition a water filled bucket and ten pound weight attached to flotation member	21	27	16	650 lb/in fabric	Samson 4" rope	Bolts	Very smooth	612	-40	Long length may be cumbersome to handle

Recovery

A discussion of oil spill recovery can be divided into two separate categories. The first involves the physical removal of the oil into a storage system. The primary means of accomplishing this is the use of mechanical oil skimmers. The second category involves an in-place treatment of the slick to remove it from the surface and disperse it into the water column or atmosphere. This category includes in situ burning, biodegradation, and the use of chemical treating agents. The use of these techniques also results in the disposal of the oil. The discussion of recovery techniques for cold region use is therefore divided into two sections, one each for mechanical recovery and non-mechanical recovery.

Mechanical Recovery

A great variety of mechanical oil spill recovery devices have been developed for use on open water. There are several factors which limit the effectiveness of all devices in open water conditions. These limitations include the type of oil; waves, currents, and winds; debris; and physical restrictions, such as piers. For example, nearly all devices are generally ineffective in wave heights greater than 1.5 to 2.0 ft, or in currents greater than 0.6 to 0.9 knots. In the arctic, there are additional conditions which further restrict the effectiveness of these devices; these include cold temperatures and ice conditions. The cold temperatures can make the device inoperable due to icing, or cause failure of many seals and bearings. Cold temperatures can also greatly affect the viscosity of the spilled oil, with nearly all devices becoming ineffective when operated in highly viscous oil. Ice conditions ranging from light slush ice to large ice floes of varying concentration further limit the usefulness of many devices. Shorefast ice creates still another spill response situation.

Commercial mechanical oil spill recovery devices were evaluated for use in cold regions after being categorized in accordance with their primary means of recovery. The available skimmers were categorized as weir, belt, disc, drum, and vortex devices. Most of the recovery devices currently on the market are of the weir type, in which oil floating on the surface of the water is separated by gravitational forces and passes over the weir which holds back the water. In the belt type, a flexible belt is drawn through the oil/water interface where the oil adheres to the belt and is subsequently squeezed from the belt into a collection sump. The disc type skimmer typically consists of a series of discs which rotate into the oil, and as the oil adheres to the disc it is lifted up, wiped off, and collected in a storage unit. As a drum type skimmer rotates, oil coats the surface and is subsequently removed from the drum into a collection sump. The vortex type of skimmer is based on inducing a vortex flow which gathers and thickens the oil for removal.

Most of the work associated with the evaluation and testing of oil spill recovery devices for cold regions applications has been conducted or sponsored by the U.S. Coast Guard. This work has consisted of field tests without oil and full-size tests performed at ARCTEC's laboratory with oil in broken ice at below freezing temperatures. The evaluation which follows is based primarily upon

these test results, and also relies on the experience of ARCTEC's staff gained during actual spill response operations, reports in the technical literature, and communications with experts in the field. The evaluation of the low temperature capability of all of the available devices incorporating a detailed review of all structural materials, fabrication methods, seals, and lubricants, was judged to be well beyond the scope of this study. Therefore, the evaluation of mechanical recovery devices for cold regions use was based upon the judged ability of the equipment to successfully interact with ice in its many forms.

Tables B-6 through B-10 are summaries of the various types of oil recovery devices presently available grouped by type. The information summarized includes the manufacturer, the device name, the type of drive used, model types, recovery rates, sizes, and a description of the operating principle. The final column contains comments relating to the cold regions application of the device.

Twenty-eight weir devices were evaluated and none were judged to be suitable in their unmodified form for use in the presence of broken ice. While none of the belt skimmers surveyed in the study offers a universal capability for recovering oil on, under, between, or sandwiched in ice, four units were judged to offer promise in limited applications. These four units are the Oil Mop, the Zero Relative Velocity Sorbent Belt, the JBF DIP, and the Bennett Oil Skimming System. Of the disc units surveyed Lockheed's Clean Sweep shows a great deal of promise for successful application in limited broken ice conditions due to its inherent ice processing ability. This ice processing ability is largely due to the rotating vanes which provide the means by which ice is swept underneath and past the recovery device while oil rises up into the collection area. Of the drum recovery devices evaluated, none appear to be suitable for use in ice conditions. The vortex devices were judged to have their suction areas quickly clogged with ice when operating in broken ice fields, and were therefore judged unsuitable for general use in cold regions.

In some applications, the direct mechanical recovery of spilled oil is augmented with the use of sorbents. These sorbents, which soak up and remove oil from the water surface, are useful in some instances. However, the major problem with the use of sorbents is the necessity for broadcasting and recovering the material. For arctic applications in the presence of broken ice cover, the recovery of sorbents would be very difficult and does not seem practical.

Non-Mechanical Recovery

Non-mechanical recovery techniques are actions that are taken when mechanical recovery is not possible, or action that can be taken more quickly than mechanical recovery in order to minimize the impact of a spill on the environment. The methods of non-mechanical recovery discussed below include:

1. In situ burning
2. Biodegradation
3. Surface collecting agents
4. Dispersants
5. Sinkants.

TABLE B-6 WEIR TYPE OIL RECOVERY DEVICES

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Acme Products, Inc. P.O. Box 51388 Tulsa, Oklahoma 74151	Floating Saucer Skimmer	Various	2 Models	to 600 and 200 gpm	46 and 64 in. dia.	Portable, floating circular skimmer	Suction likely to be blocked by broken ice.
Bennett Pollution Controls 119 Charles Street North Vancouver, B.C. Canada V7H1S1	Sea Hawk	None	-	Capacity 100 gal	4 ft. dia.	Portable, floating circular skimmer	Likely to clog with broken ice.
Coastal Services, Inc. 22 River Street Braintree, Mass. 02184	Slurp Skimmer	Gasoline Engine	-	to 33 gpm	35.8x24.5x 16.5 in.	Portable, floating, self-adjusting depth skimmer	Designed for +32°F to +120°F; suction likely to be blocked with broken ice.
Core Laboratories 7501 Stemmons Freeway Dallas, Texas 75027	Core Skimmer	Towing Vessel Required	-	to 800 gpm	to 60 ft wide	Triangular flat funnel of fabric on a rigid frame	Likely to clog with broken ice.
Crisafulli Pump Co.Inc. Box 1051 Glendive, Montana 99330	Aqua-Sweeper	Gasoline Engine	-	to 500 gpm	16x7x5 ft	Self-propelled catamaran vessel with integral weir	Suction likely to be blocked by broken ice.
Environmental Protection Machines Ltd. Rte 2, Box 97 Estacada, Oregon 97023	Skimmer	Diesel	3 harbor sizes	to 5,000 gpm	16x6 ft to 80x15 ft	Free floating weir skimming system mounted between catamaran hulls	Suction likely to be blocked by broken ice.
John Finney & Co. 4217 SE River Dr. Milwaukee, Oregon 97222	OEPM	Gasoline Engine	3 models	to 5,000 gpm	20 ft x 8 ft	Self-propelled catamaran vessel with integral wear	Likely to clog with broken ice.

TABLE B-6 WEIR TYPE OIL RECOVERY DEVICES (Cont'd)

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Industrial & Municipal Engineering 0.0. Box 61 Galva, Illinois 61434	OELA-III	Pump not supplied	-	-	4.5 ft dia.	Portable, floating, circular skimmer	Likely to clog with broken ice.
MacMillan-Bloede, Ltd.	OS-48-W Skimmer	-	-	-	-	Upward sloping weir that leads into a baffled area, oil overflows into a trough in the baffled section and is pumped from there.	
Megator Corp. 136 Gamma Drive Pittsburgh, Pa. 15238	Megator Skimmer	Various	4 Models	-	7.5x3.8 in. to 4.3x4.0 x 3.8 ft	Small, portable floating or hand-held skimmers	Likely to clog with broken ice.
Metropolitan Petroleum Petrochemicals Co., Inc. 25 Caven Point Road Jersey City, N.J. 07305	MASH-400	Electric	400	to 400 gpm	6.5x6 ft	Free floating adjustable weir	Suction likely to be blocked by broken ice.
Mitsui Ocean Development & Engineering Co., Ltd. Tokyo, Japan	MIPOS	Diesel	3 sizes	to 130 gpm	20x8x5 ft to 56x20xft	Oil is concentrated by moving down a fixed inclined plane, passes into a baffled well, and is collected by a weir	Suction likely to be blocked by broken ice.
Neyrpic, Inc. 375 Park Avenue New York, NY 10022	Skamil System	Pump not supplied	Industrial	-	custom	Fixed weir in conjunction with a constant upstream level gate	Likely to clog with broken ice.
Oceaneering Intl. Inc. 9219 Katy Freeway Houston, Texas 77024	Sweep Skimmer	Diesel Engine	-	to 50 gpm	25x10 ft	Self-propelled catamaran vessel with integral weir	Suction likely to be blocked by broken ice.

TABLE B-6 WEIR TYPE OIL RECOVERY DEVICES (Cont'd)

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Ocean Systems Incorporated 11440 Issac Newton Sq.No. Reston, Virginia 22090	Ocean Systems ORS	Various	4 sizes	125 to 2000 gpm	2.6 to 62 ft long	Double weir floating skimmer generally used with booms	Suction likely to be blocked by broken ice.
Offshore Devices Building 43 Summit Industrial Park Peabody, Mass.	Skimmer Barrier	Hydraulic	-	600 gpm	23 in wide, 20 in long	Three weir systems are integral of containment barrier 650 ft in length	Suction likely to be blocked by broken ice
Parker Systems, Inc. P.O. Box 1652 Norfolk, VA 23501	Oil Hawg	Pneumatic	-	to 120 gpm	43 in dia. x 16 in high	Portable, floating circular skimmer	Suction likely to be blocked by broken ice.
Pembina Equipment Design Co., Ltd.	Four-foot automatic skimmer	-	-	-	-	Hydro-adjustable weir skimmer with trash screen	
Oil Recovery Systems Greenville, N.H. 03048	Scavenger	Electric	-	5 gpm	17-1/2" dia.	Portable, fixed weir	Suction likely to be blocked by broken ice.
Rheinwerft GmbH & Co. Mainz-Mombach West Germany	Rheinwerft Skimmer	Various	4 sizes	to 177 gpm	well dia. 20 to 118 in	Circular weir for stationary use in industrial applications.	Suction likely to be blocked by broken ice.
Seaward International 6269 Leesburg Pike Falls Church, Va. 22044	Spiltrol Harbor Skimmer	Diesel	-	to 50 gpm	25x10 ft	Oil passes through tube bundle and baffle arrangement to collection well and is removed by chevron or veir recovery head	Suction likely to be blocked by broken ice.
Seaward International 6269 Leesburg Pide Falls Church, Va. 22044	Streaming Fiber Recovery Device	Hydraulic	-	-	Fiber box 17 ft long by 35 ft wide	32 ft catamaran hull; Fiber array, endless belt and weir mounted between hulls.	Suction likely to be blocked by broken ice.
Shell Development Co. Westhollow Research Center Houston, Texas 77001	SOCK	Towed a alongside workboat	-	330 gpm	25 ft wide, 43 ft long, 4.5 ft draft	Frame-supported rubber SOCK mounted both sides abeam work vessel	Bag may become blocked with ice.

TABLE B-6 WEIR TYPE OIL RECOVERY DEVICES (Cont'd)

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Seaward International 6269 Leesburg Pike Falls Church, Va. 22044	Huskey Offshore Skimmer	For pump only, not Self-propelled	-	to 1400 gpm	42x16x10 ft	Double adjustable weir between catamaran hulls, adjustable bow plane and adjustable collection well weir	Suction likely to be blocked by broken ice.
Skim, Inc. 1532 So. Sur I Drive Los Angeles, Calif. 90023	Skimine Oil Skimmer	Various	Several	to 105 gpm	-	Small portable floating circular weir skimmers	Suction likely to be blocked by broken ice.
Slickbar, Inc. P.O. Box 139 *Southport, Ct. 06490*	Slickskim	Pump not supplied	5 skimming heads	to 250 gpm	to 48x4 in	Flexible and rigid hand-held skimmers	Likely to clog with broken ice.
Sunshine Chemical Corp. P.O. Box 5534 Jacksonville, Fal 23307	Sea Broom	Gasoline Engine	-	to 715 gpm	48 in dia.	Small, portable, flotaing skimmer	Likely to clog with broken ice.
Trygve Thune A/S Munchsgate 5 Oslo 1, Norway	T-T Oil Recovery System	Diesel	Harbor and ocean vessels	to 110 gpm for harbor vessel, 2100 gpm for ocean	23x8x4 ft to 102x32.8x 16.4 ft	Oil and water enter a settling chamber from which oil is removed or stored while water discharges from bottom. Harbor unit uses paddle wheel for suction	Suction likely to be blocked by broken ice.
Ultrasystems, Inc. 2400 Michelson Drive Irvine, California 92715	Streamlined Oil Boom/Skimmer	Water Flow	-	44 gpm, 1 ft width of opening for 3 mm slick	4 ft wide mounted between hulls of 34 ft catamaran	Weir mounted between hulls of catamaran or moored in a high current flow	Likely to clog with broken ice.

TABLE B-7 BELT TYPE OIL RECOVERY DEVICES

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Aerodyne Development Corporation 29085 Solon Road Cleveland, Ohio 44139	Aerodyne Belt Oil Skimmer	Electric	5 sizes	0.5 to 3 gpm	7 to 70 in wide	Vertical moving steel belt with wipers designed for fixed installation	Applicable temperature range listed as 70 to 200°F; suction likely to be blocked with broken ice.
Bennett Pollution Controls, Ltd. 119 Charles Street North Vancouver, B.C. V7H 1S1 Canada	Bennett Oil Skimming System	Diesel	Harbor, inshore & offshore models	to 250 gpm	to 40x12 ft vessel	Self-propelled vessels using absorbent belt in conjunction with weirs	Suction likely to be blocked by broken ice; recovery of small ice pieces could hamper squeeze belt operation.
Centri-Spray Corp. 39001 Schoolcraft Rd. Livonia, Michigan 48150	Centri-Clere Oil Recovery Unit	Electric	--	0.5 to 3 gpm	26 x41 x96 in	Fixed installation, moving synthetic composition belt with wipers	Has been operated to 0°F with heated enclosure; suction likely to be blocked with broken ice.
JBF Scientific Corp. 2 Ray Avenue Burlington, Mass. 01803	JBF DIP	Various; units self-propelled	5 sizes, harbor to ocean	to 550 gpm	6x3.5x3 ft to 35x11x18 ft	Oil follows moving belt to a collection well; separation by buoyancy	Suction likely to get ice-clogged; has potential of being easily adapted for processing of broken ice pieces.
Marco Pollution Control 2300 West Commodore Way Seattle, Wash. 98199	Marco Oil Recovery System	Various, stationary & self-propelled	6 sizes, industrial to ocean	to 400 gpm	34x30x36 in to 57.5x23.5 ft	Oil collects in the open cells of a moving foam belt & is wrung out	Suction likely to be blocked by broken ice; could recover small oil-coated ice pieces.
Ocean Design Engineering Corp. 600 East Ocean Street Long Beach, Calif. 90802	Sop Skimmer, Swath Skimmer	Diesel	Open water, sheltered water	to 1,610 gpm	44.5x18.5 ft to 33x10 ft	Self-propelled vessels using absorbent belt to recover broadcasted absorbents	Broken ice likely to be recovered with absorbents; would require additional separation.

TABLE B-7 BELT TYPE OIL RECOVERY DEVICES (Cont'd)

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Oil Mop, Inc. Engineers Road Belle Chasse, La. 70037	Oil Mop	Various	Hand mops to 36 in dia ropes	560 gpm	18x24x36 in to 10x12x9 ft	Belt of poly-propylene strands woven in a rope, passed through a wringer	Applicable in solid ice cover if threaded through ice, and in broken ice cover; temperature range speci-fied as -40°F to +210°F.
Oil Mop, Inc. Engineers Road Belle Chasse, La. 70037	Oil Mop Dynamic Skimmer	Diesel	6 contin-uous loop, 10", 35 ft long ropes	175 gpm	40 ft cata-maran, 13 ft beam	Continuous loop mops, passed through wringer	Shows potential for moving over and processing oil-coated ice in a broken ice field.
Oil Skimmers, Inc. 1803 W. Royalton Rd. Cleveland, Ohio 44147	Brill Skimmer	Electric	Vertical & Horizontal	to 2 gpm	23x15x9.3 in to 50.5x12.4 x10 in	Free floating tubular collection belt with wipers	Applicable in solid ice cover if threaded through ice and in broken ice cover, low temperature data unavailable.
R.B.H. Cybernetics (1970) Ltd. P.O. Box 4205, Postal Station A Victoria, B.C. Canada	Slick-licker	Various	-	-	6x6x6 ft; 11 and 15 ft booms	Oil collects on oleophillic/hydro-phobic endless belt and is removed by squeeze rollers	Suction likely to be blocked by broken ice; could recover small oil-coated ice pieces.
Rex Chainbelt, Inc. Milwaukee, Wisc. 53201	Rex Belt Skimmer	Electric	12 in and 24 in belt widths	-	1.7x2x2.8 or 3.8 ft	Fixed vertical in-stallation, endless synthetic belt with doctor blades	Suction likely to be blocked by broken ice.
Sandvik Conveyor, Inc. 1650 McBride Ave. Fair Lawn, NJ 07410	Sandvik Belt Skimmer	Electric	8 and 24 in belt widths	to 2 gpm	29x32x20 in to a 30 ft boom	Fixed installation rotating steel con-veyor belt with a wiper	Suction likely to be blocked by broken ice; designed for fixed installations.
Shell Development Co. Westhollow Research Center Houston, Texas 77001	ZRV Sorbent Belt	-	Test		40 ft belt, 7 ft wide	Endless belt has 0 velocity relative to water; wringer removes oil from belt	Shows potential for application in broken ice field; freezing of the felt/astro turf belt may damage the belt and wringer.

TABLE B-8 DISC TYPE OIL RECOVERY DEVICES

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
BP North America, Inc. 620 Fifth Avenue New York, NY 10020	Vikoma Sea-skimmer Komara Mini-skimmer	Hydraulic Pneumatic	- -	500 to 50 gpm	11 ft dia 46 in dia	Toroidally disposed rotating plastic discs	Suction likely to be blocked with broken ice, discs may not be of sufficient strength to process ice.
Centri-Spray Corp. 39001 Schoolcraft Rd. Livonia, Mich. 48150	Centri-Clere Oil Skimmer	Electric	-	to 10 gpm	8'9"x9'10" x4'0"	Two rows of rotating plastic discs	Designed for +32°F to +120°F; likely to get ice-clogged.
Lockheed Missiles & Space Co., Inc. P.O. Box 504 Sunnyvale, Calif. 94088	Clean Sweep	Various	Portable to oceangoing	15 to 1000 gpm	48x48x26 in to 10x23x27 ft	Parallel vertical rotating metal discs	Has inherent ability to process or "walk-over" small ice pieces thereby separating oil from ice.

TABLE B-9 DRUM TYPE OIL RECOVERY DEVICES

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Peabody Welles, Inc. Roscoe, Illinois 61073	Reclamator	Electric	-	to 60 gpm	12x5x7.5 or 9.8 ft	Floating, rotating, foam-covered drum with squeeze rollers to separately remove oil and water	Not recommended for use in broken ice, foam can freeze destroying drum, but would appear to be adaptable for ice processing.
Surface Separator Systems, Inc. 103 Mellor Avenue Baltimore, Md. 21228	SSS Skimmer	Various	Several industrial skimmers plus harbor barges	to 600 gph	to 79x66x38 in for industrial; to 38.5x16.5 ft barge	Oil coats rotating dual plastic cylinders and is removed by wipers	Suction likely to be blocked by broken ice.
Worthington Corp. 401 Worthington Ave. Harrison, N.J. 07029	Mop-Cat	Gasoline Engine	-	to 100 gpm	33x12 ft	Foam covered rotating drum on a self-propelled catamaran vessel	Recommended temperature range +32°F to +120°F, but would appear to be adaptable for ice processing; if foam and wringer is not damaged by freezing.

TABLE B-10 VORTEX TYPE OIL RECOVERY DEVICES

Manufacturer	Device	Type of Drive	Model	Rating	Size	Description	Comments Related to Cold Regions
Alsthom Techniques Des Fluids B.P. 75 Grenoble, France	Cyclonet	Various for pump only	Several sizes for industrial to offshore use	45 to 1600 gpm	from 1.6x4.9 x3.3 ft upwards	Water and oil drawn in through tangential slit by forward motion or pump suction, rotary flow causes natural separation	Suction likely to be clogged with ice.
Intex, Inc. 6935 Wisconsin Ave. Chevy Chase, Md. 20015	Vortex Oil Drinker	Pneumatic or Electric	Industrial, harbor & offshore models	to 50 gpm and 100 gpm for industrial units	12 ft dia x 6.7 ft high, and 13x17x11 ft for industrial units.	Oil gathers in the center of a vortex generated by a propeller and is pumped out (Elf-Bertin process).	Suction likely to be clogged with ice.

In Situ Burning

Because of the remoteness of potential Alaskan spill sites, it is likely that in situ burning would be more acceptable in the arctic than might be the case in more heavily populated areas of the lower 48 states. The burning of oil on open water, in between broken ice, and on the surface of ice will likely serve as an important oil pollution countermeasure in the arctic.

In situ burning on open water depends on the way in which oil vaporizes and burns as a thin film on water. The combustion of fuel occurs in the vapor phase. The water acts as an infinite heat sink, taking heat away from the fuel. Analysis of burning pools of oil indicate that oil will burn at a rate of about 1.5 millimeters per minute from the surface of a spill. As the layer of burning fuel thins, the heat conducted away by the water begins to equal the heat back-radiated by the flame. At this point the rate of burning and the height of the flame both decrease. As the fuel layer becomes still thinner, a temperature is reached at which there is no longer enough fuel vaporization to maintain the flame in competition with heat loses to the water. When the liquid fuel reaches this temperature, known as the fire point, the flame goes out. Generally most crude oils burn out when the slick thickness on water falls below 5 millimeters. When special wicking agents are used, this thickness may be reduced to about 2 millimeters.

The operation of the wicking devices is dependent upon the capillary rise of oil through the wick, and upon the vaporization and combustion of the oil. Ideally wicking agents should be hydrophobic, oleophillic, flame resistant, non-combustible, and contain channels of optimum capillary diameter for oil to move upward. Since large quantities of wicking agents are often required, these agents should also be inexpensive and easy to manufacture. In a study conducted by Environment Canada AMOP [1], six wicking materials were evaluated. In general, Nomex and interwoven polypropylene cord materials performed best in the tests. In the tests of these cord materials, the wick operated effectively for a maximum period of one hour. After this time, the flames spread over the entire slick completely destroying the wicking material. Work is in progress to eliminate this problem. This study also considered ignition of the wicking material by a timing system, radio signals, and by an oil slick detection device. The timing system was considered as the most reliable and inexpensive and a prototype was built and tested [1].

Providing the slick is thick enough to support combustion, which means at least 5 millimeters for crude, direct burning by air-deployable igniters is feasible. The igniter must supply sufficient energy to initiate and maintain local heating and volitization of oil near the igniter, local ignition of oil vapors near the igniter, and flame spread to the entire slick surface. To meet these requirements, five igniters were tested under the Environment Canada AMOP program [1]. The igniters tested include Kontax, solid propellant, solid fuel, and sodium and gasoline igniters.

Kontax igniters were designed mainly for the purpose of oil slick combustion, and had been previously used in air deployment applications.

Solid propellant igniters have the advantage of providing a strong flame which is not likely to be extinguished under windy conditions. Solid fuel igniters are inexpensive and have the advantage of not being rapidly consumed by flames. The sodium and gasoline igniters also have the advantage of being very inexpensive to manufacture. Solid fuel, solid propellant, and Kontax igniters were effective in oil slick ignition, having ignition probabilities of 84%, 89% and 100% respectively.

Delayed activation of air-deployable igniters can be achieved by using separate starters. These starters include chemical, electrical, and fuse wire starters. Field tests showed the most effective starter/igniter combination to be fuse wire starters used with solid fuel and solid propellant igniters. The probability of ignition for this combination was 80%. Problems encountered in air deployment of the igniter/starter combinations include damage by landing impact and splashing the oil away from the igniter when landing. Future research by Environment Canada is planned.

It also seems reasonable that oil in between ice floes could be burned provided the oil thickness is adequate. The broken ice could help contain the oil to a thickness great enough for effective combustion to take place. Special containment barriers could also be used to help contain the oil for burning. Some fire resistant commercial booms are presently being tested as part of the Environment Canada AMOP program.

Even in cold regions where the oil is partially contained by the ice, in situ burning is likely to be an effective spill countermeasure. Approximately 80 to 95% of a slick can be eliminated from the surface of the water or ice by using this method. Research is still required to address some of the problems associated with air deployable wicking agents, igniters and starters. These problems include safety in handling and transportation, reliability, chemical stability, and splashing oil away from the igniter on impact. Problems are also involved in obtaining permission to carry these devices in various classes of military and civilian aircraft. If a variety of devices are approved for use, there is also a problem of uniformity of air launchers, particularly for multi-national use.

Biodegradation

Microbial degradation of petroleum depends on the chemical composition of the spilled oil, the enzymatic capabilities of the microorganisms and the environmental conditions. In the arctic, microorganisms must be capable of degradation at low temperatures which in turn tends to limit the rates of their degradative activities [2, 3]. While little can be done to manipulate temperature, it should be noted that spilled oil may absorb solar radiation and raise the temperature around the spills, making it more favorable for microbial activities. Additionally, petroleum hydrocarbons can be degraded at low temperatures [2, 3, 4] and the presence of ice crystals may actually stimulate this process [5]; however, if the oil is isolated and preserved in ice, the biodegradation process fails to occur [1]. Crude oils from the arctic, such as Prudhoe crude, contain heavy complex hydrocarbons which are difficult for microorganisms to attack, but on the other hand, such crudes also lack a volatile fraction which is toxic to microorganisms [6]. Other factors influencing biodegradation, such as limitation on the usable forms of nitrogen and phosphorus, which is characteristic of marine ecosystems, may be

overcome by appropriate addition of a suitable fertilizer [7]. The fertilizer formulation should be of a usable form which will not add appreciably to the high BOD of spilled oil. Also, limitation on the low numbers of oil degrading microorganisms may be overcome by seeding [8, 9]. The inoculum will have to be composed of a mixture of microorganisms that are capable of enzymatic activities at low temperatures and that are also capable of degrading the wide variety of hydrocarbon structures found in crude oil. Ideally, the microorganisms will convert these hydrocarbons to carbon dioxide. More research is required to investigate further the effectiveness of fertilizers, and degradation rates of oil under various snow and ice interactions.

Surface Collecting Agents

Surface collecting agents are chemicals that are applied along a spill boundary to prevent further spreading or to compress thin films into thicker ones. The basic requirement of these collecting agents is that their spreading pressure be greater than that of the spilled oil.

Annex 10 of the National Oil and Hazardous Substances Pollution Contingency Plan has recently been extended to approve certain chemical treating agents for use in combating spills. As of February 1978, the only surface collecting agent which had been approved is the Shell Oil Herder. The Oil Herder has been successfully applied at temperatures down to 25°F by keeping the solution agitated, however, the product normally solidifies at temperatures of 36°F and because of this, would not perform satisfactorily in most Alaskan environments.

Dispersants

Since the grounding of the TORREY CANYON in March 1976, the use of dispersants has been severely criticized by many groups throughout the world. However, with the recent development of less toxic and more effective dispersants, their use has become more widely accepted. Dispersants are chemicals that are applied to an oil slick to create an oil-in-water emulsion. The resulting emulsion consists of tiny droplets of oil and dispersant which become distributed in the water column. The mixing of the spilled product limits spreading on the surface, increases the surface area of oil available for biodegradation, and limits some forms of environmental damage generally associated with surface slicks, such as damage to water fowl.

Several self-mixing dispersants have recently been developed. These agents use chemical diffusion rather than mechanical mixing to disperse the droplets into the water column. These self-mixing dispersants produce a smaller, more uniform oil droplet size when compared to dispersants which require mechanical mixing. More importantly, these dispersants do not require much external energy to disperse the oil into the water column.

The effectiveness of a dispersant is indirectly related to the slick thickness; that is, the thinner the slick, the more extensive the dispersion. Thicker oil often has a higher oil viscosity, which in turn is related to the air and water temperature. Therefore, the effectiveness of dispersants will be

adversely affected by cold temperatures. A thick slick, or one having a high wax or asphalt content, requires the use of more dispersant. For example, one part dispersant is generally adequate to break ten parts of oil. For oils with high asphalt content or at very low temperatures, three or four times that amount of dispersant may be required.

There seems to be direct relationship between changes in viscosity due to temperature and percent dispersal in the range of 5° to 20°C [10]. Taking 20°C and 100 percent dispersion as a basis, the decrease in temperature to 10°C caused a factor of two decrease in percent oil dispersed. Similarly, percent of dispersion dropped by a factor of three as the temperature dropped from 20°C to 5°C. Although these test results are preliminary, they do indicate that dispersants have reduced effectiveness at lower temperatures.

The Environment Canada AMOP sponsored a program investigating the application of dispersants in the Southern Beaufort Sea [1]. This study found that regardless of the application method, it costs $444 to purchase and deliver 264 gallons of dispersant to a spill site or $1.68 per gallon delivered. To this must be added the cost of applciation, which for aircraft platforms would be in the neighborhood of $65 per 264 gallons or another $.25 per gallon. Therefore, the total cost to disperse 5.3 million gallons of oil would be more than 10 million dollars. These costs do not include ancillary equipment and manpower.

In addition to the influence of temperature on oil dispersant effectiveness and high costs of application, local environmental conditions affect the use of dispersants in the arctic regions. The effectiveness of dispersal depends on the volume of water in which the oil will disperse, which is in turn influenced by water depth, and water turbulance. Waters along many sections of the Alaskan coast are shallow providing a small volume of water for dispersion. In addition the effects of ice tend to dampen wave action which decreases the energy available for dispersion. In spite of these problems, dispersants may still be the most effective spill countermeasure available in some situations.

Dispersants used in the coastal waters of the United States must be approved by the Environmental Protection Agency. Dispersants accepted for use by the EPA as of February 1978 are listed in Table B-11.

Sinkants

A variety of sinking agents have historically been employed to prevent oil from spreading or to remove the environmental hazard of the oil slick on the water surface. Current federal regulations contained in Annex 10 of the National Oil and Hazardous Substances Pollution Contingency Plan prohibit the use of sinking agents.

TABLE B-11 OIL SPILL DISPERSANTS CURRENTLY ACCEPTED BY EPA

Manufacturer	Dispersant	Application Rate (Parts Agent/Parts Oil)	Flammability (Flash Point)	Environmental Toxicity (Safe Below PPM)	Biodegradability
Adair Equipment Co. 5518 Mitchelldale Houston, Texas 77024	Cold Clean	Mixed to 1/1000 to 3300 parts water for application	None	75 to 240 (Depending on Test Species)	-
ARA Chem, Inc. P. O. Box 5031 San Diego, Cal. 92105	GOLD CREW	1/2 to 3	None; water based	15 - 20	>90%
BP Oil, Ltd. Britainnic House More Lane London E.C. 2Y9,BU England	BP 1100 X	1/10 for black oil, 1/1 for weathered oil	185°F	>10,000	Biodegradable
CGC Chemical Co. 2539 Oil Okeechobee Rd. West Palm Beach, FL 33409	Atlantic & Pacific	1/1 to 50 parts water for application	No flash	-	99% in 7 days
Whale Chemical Co. 58 Winant Street Staten Island, NY 10303	Sea Master NS-555	1/20 to 30 light oil 1/5 to 10 heavy oil	None	3,000	95% in 10 days

Transfer Systems

Background

In a typical arctic spill scenario, transfer systems are used to move oil collected in recovery devices or surface skimmers into the tanks of a barge or other storage device. In some cases the oil may be pumped directly from locations where it has pooled on shorefast ice or collected in openings in shorefast ice. In all cases, the oil may be mixed with ice and other debris. When the oil is mixed with sea water and ice, the resulting mixture can be expected to be no lower than about 28°F even though the ambient air temperature may be much lower. Oil pooled on ice may have a very low temperature if it is not recovered immediately after it has been spilled. When air temperatures are extremely low, this oil may also become highly viscous. This condition will require special pumping systems and equipment; in the extreme case the oil may be removed by scraping.

Transfer systems, then, operating in an arctic environment must be capable of functioning at extremely low ambient air temperatures, they must have the ability of moving an oil/water/ice mixture, and in some cases, they must be able to move oil with high viscosity resulting from very low temperatures.

In considering the problem of moving fluids one immediately thinks of a pump; however, when considering moving fluids in the arctic it is necessary to include the entire transfer system. The basic elements of such a transfer system may generally be thought of as including a prime mover, a pump, a hose, and the fluid to be moved, which in this case is the oil or an oil/water/ice mixture. The paragraphs that follow briefly describe the elements of the transfer system and the special problems each system element may have in the arctic environment.

Transfer System Components

- The Prime Mover - This system element is the power source for the transfer system. The prime mover is generally a gasoline engine, diesel engine, or a gas turbine. In addition to the usual space, weight, and power requirements, the prime mover in the arctic has problems in starting and operating in extremely cold temperatures. In the cold weather tests of the Coast Guard ADAPTS system, the air cooled diesel prime mover was started at an air temperature of -40°F, but some problems were involved [14]. For example, it was necessary to spray ether directly into the air intake filter and crank the engine much longer than normal to achieve a successful start. Other problems also had to be solved: air cooling had to be reduced to get normal engine operating temperature; special lube oil was required; the engine oil temperature gage did not operate at -40°F; synthetic rubber seals and gaskets leaked; engine V-belts cracked; seals leaked in the hydraulic drive unit for the systems submersible pump, and special hydraulic fluid was required. These problems were solved by identifying special seals and gaskets, special fan belts, and special fluids to use in the various systems.

These kinds of problems may be expected in adapting any prime mover for use in the arctic.

As an alternative to starting the prime mover at extremely cold temperatures, it is common arctic practice to enclose the engine in a heated shelter or to use a portable heater to bring the engine up to a higher temperature before attempting to start it. Once started, the diesel may be kept running as long as it is needed. Although this reduces the starting problem, many of the same precautions for cold weather starting still apply.

• The Pump - Although a great many different kinds of pumps are suitable for transfer systems in the lower latitudes, the requirements of low temperature operations generally limit those available to one or two choices. The special problems involve high viscosity of oil at low temperatures and the requirement to pass some ice and debris along with the recovered product. The pumps that may be considered for use in this system include diaphram, centrifugal, positive displacement or progressive cavity, and vertical turbine pumps. Air, steam, and hydraulic lift systems are generally not practical for these transfer systems because of the nature of the fluid to be moved and the way in which system components must be arranged.

Recent tests of centrifugal, positive displacement, and vertical turbine pumps clearly show the relative effectiveness of these devices in moving cold, highly viscous oils [13]. Although five separate pumps were evaluated in these tests, the system tradeoffs can be illustrated by just showing results for each pump type.

The test used the heavy No. 6 Bunker-C oil as a test fluid. Although this oil is much more viscous than crude oil, which may be about equivalent to No. 4 oil, crude oil may have a comparable viscosity in the arctic as a result of being pooled on ice in extremely low ambient air temperatures. Figure B-1 shows the general range of oil viscosity according to the fuel number designation. The pumps selected to illustrate general system capabilities are the Prosser centrifugal pump, the Moyno progressive cavity pump, and the Byron-Jackson vertical turbine pump. Figures B-2 through B-4 show the results of these tests in terms of flow and pressure for various oil temperatures.

Figure B-2 shows that the centrifugal pump has a high flow capacity as long as the temperature of the fluid is relatively high but as the temperature drops, and oil viscosity increases, the flow capacity also drops rapidly. Figure B-3 shows similar capability for the vertical turbine pump. Figure B-4 shows that the progressive cavity pump has a generally lower flow rate but the rate is not reduced nearly as much as a result of change in temperature. In this particular test the vertical turbine pump was found to be unsuitable for pumping highly viscous oil. Although this particular study found the centrifugal pump to be best for pumping viscous oil, the progressive cavity pump is generally best for arctic use because it is effective for a wide range of oil viscosity and also has a high tolerance in pumping water, debris, and ice mixed with the oil. Also, in extremely cold weather, centrifugal and

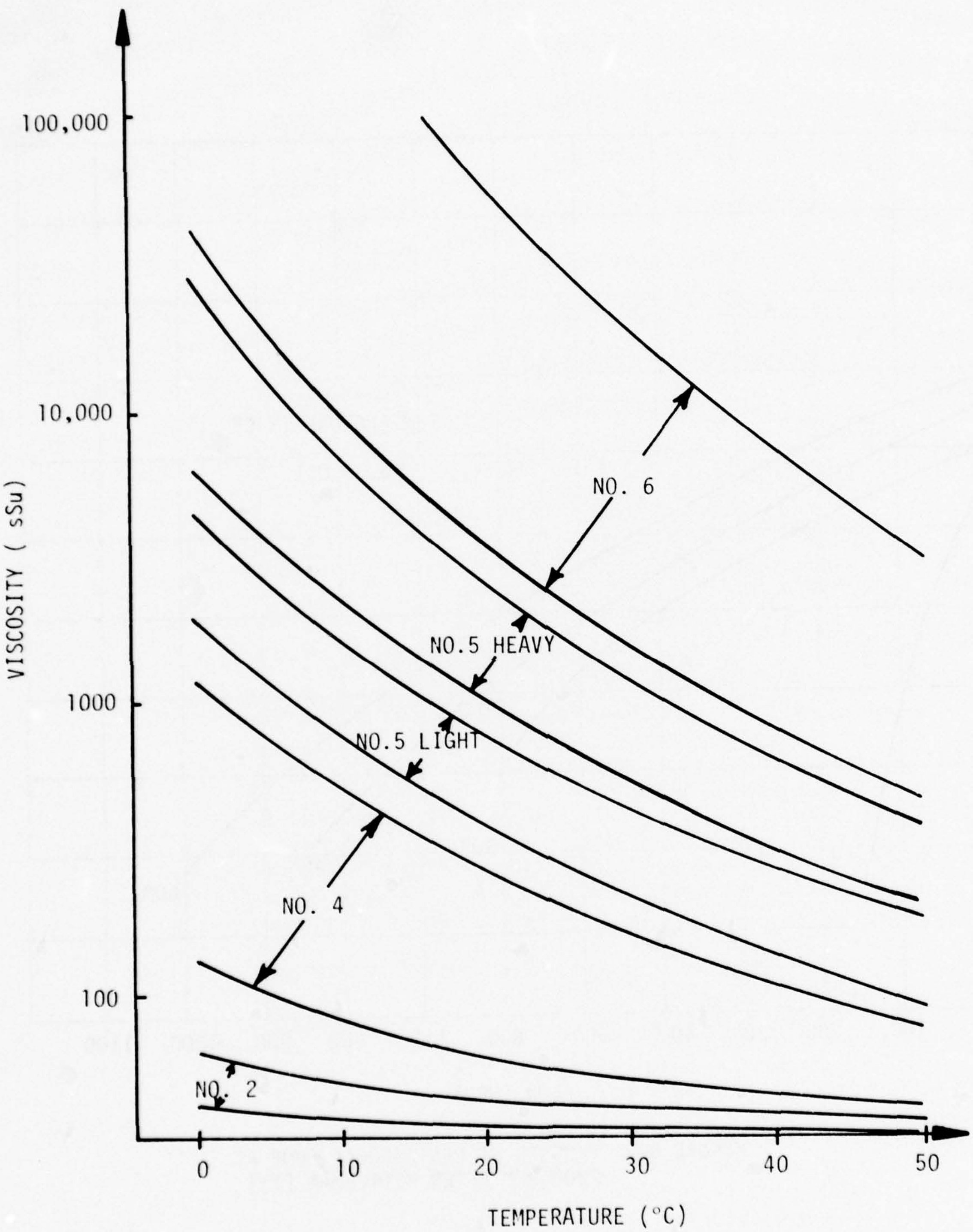

FIGURE B-1 TEMPERATURE-OIL VISCOSITY RELATIONSHIP [13]

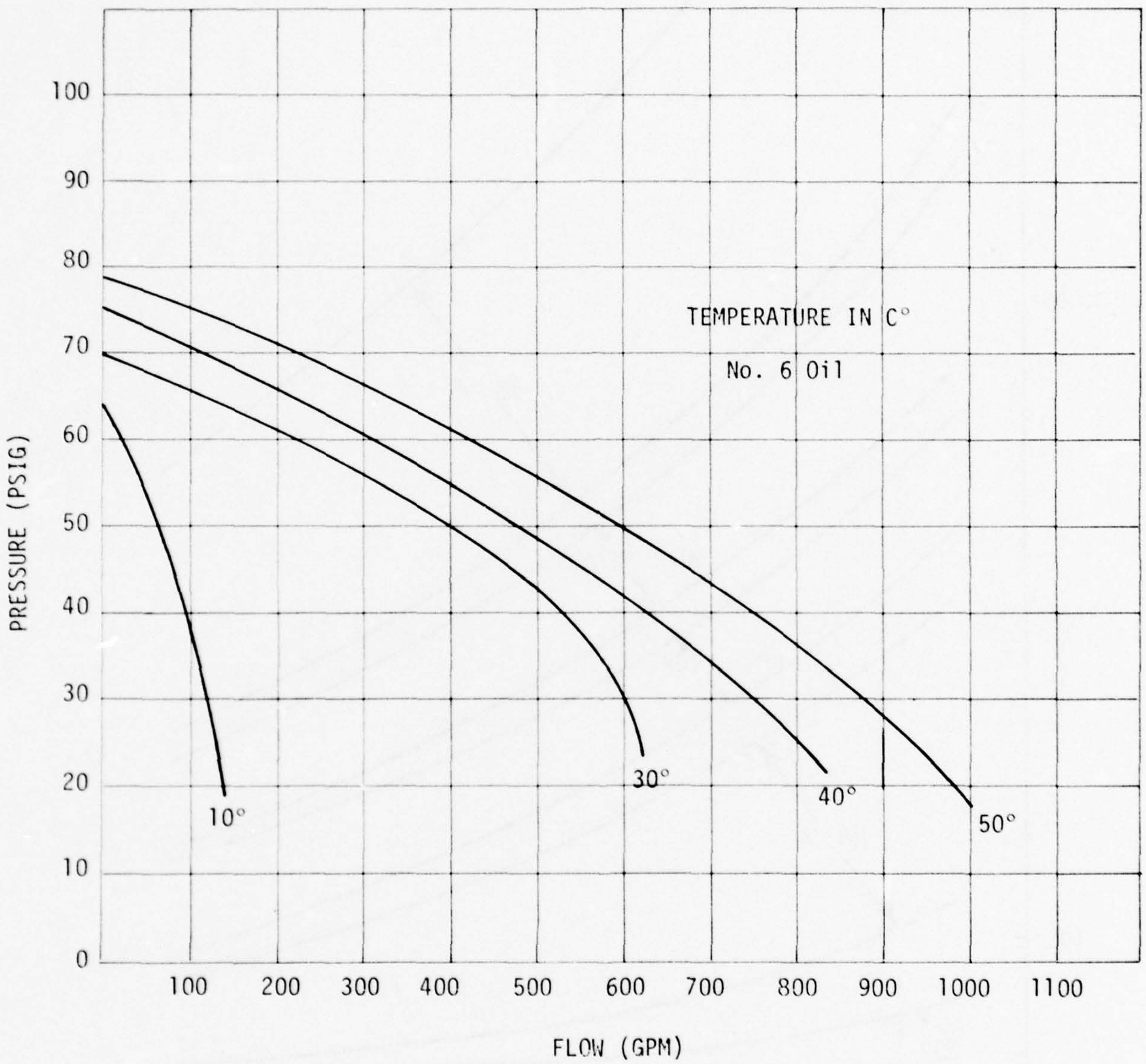

FIGURE B-2 PROSSER #1 CENTRIFUGAL PUMP AT 2200 RPM AFTER MITTLEMAN [13]

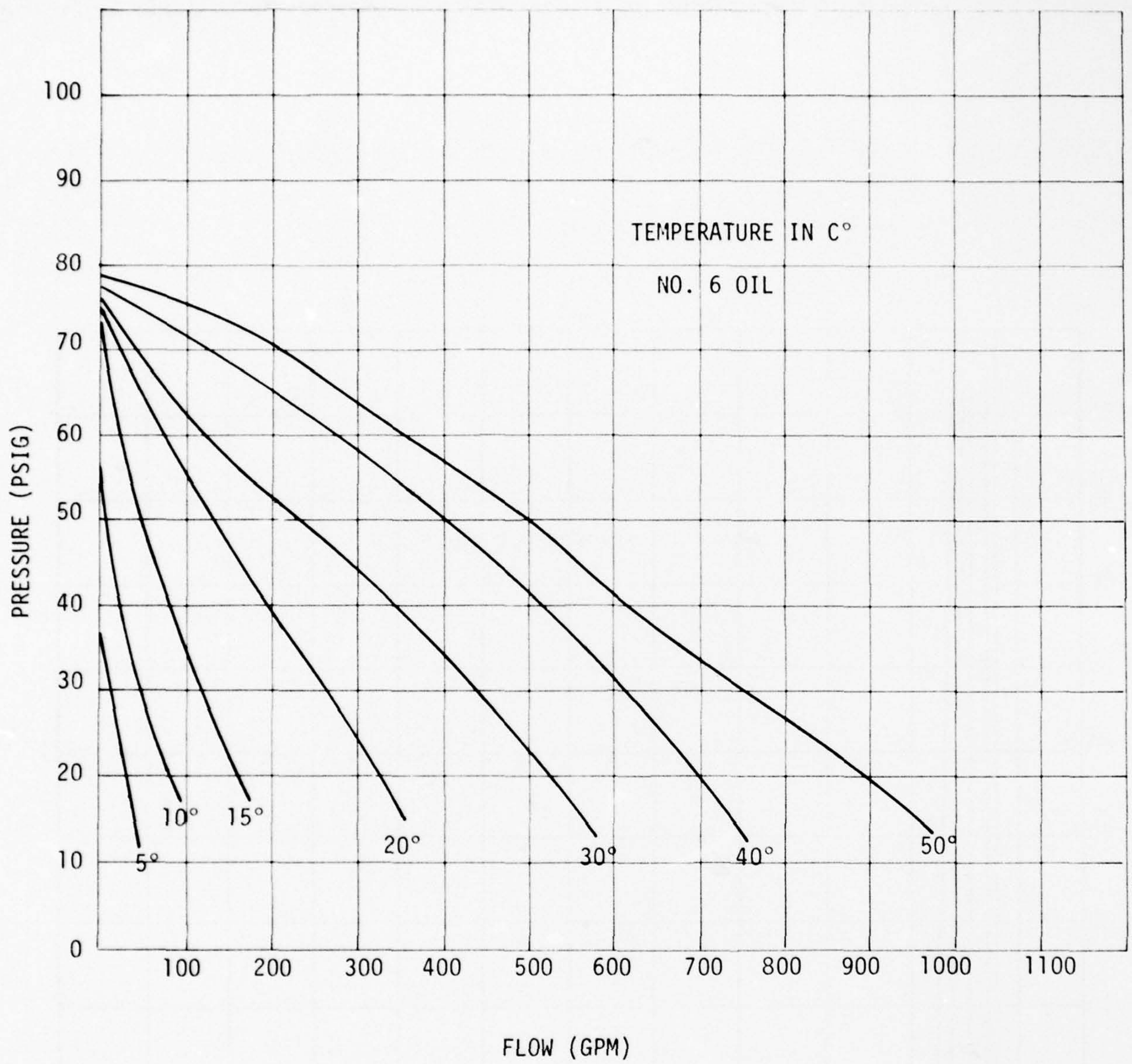

FIGURE B-3 BYRON JACKSON VERTICAL TURBINE PUMP AT 2200 RPM AFTER MITTLEMAN [13]

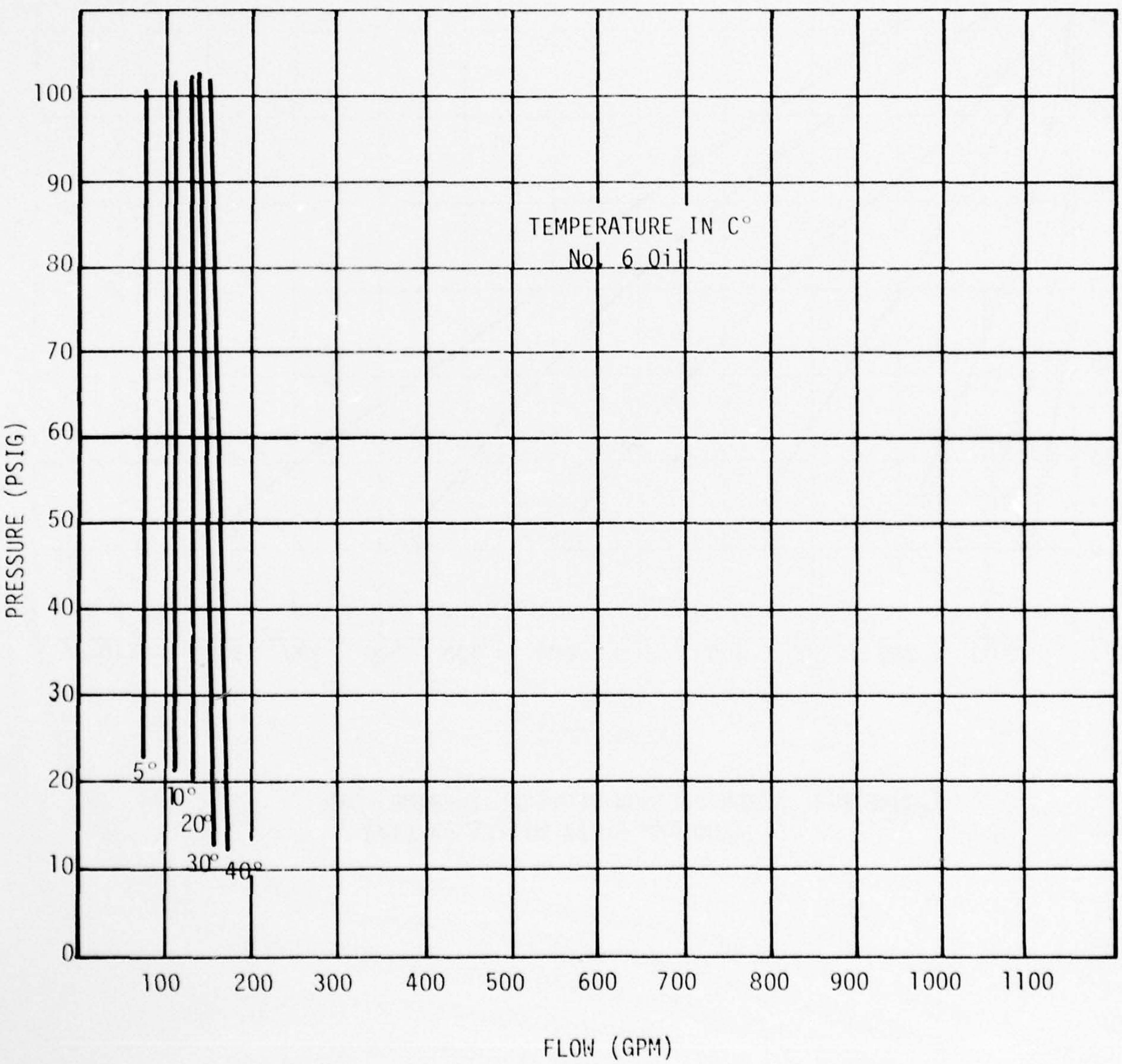

FIGURE B-4 MOYNO PROGRESSIVE CAVITY PUMP AT 2200 RPM AFTER MITTLEMAN [13]

vertical turbine pumps have problems with impeller clearances and pump seals. The progressive cavity pump has a helical steel rotar inside a helical synthetic rubber stator. The soft stator gives it capability to pass fairly large solids and it does not have the cold weather problems of clearances typical of the all-metal pumps [12].

• The Hose - A normal pump discharge hose, such as the one used in the ADAPTS system, is generally only suitable down to 0°F and may be brittle and crack at temperatures of -40°F [14]. This hose therefore must be replaced with special low temperature hose plus low temperature seals. Although the product mixture may be considered to be at +28°F, the oil/water/ice mixture may still freeze and clog the hose if there is a considerable distance between the pump and storage container or if the hose rests on cold shorefast ice. To prevent clogging by freezing it may be necessary to insulate the hose or even heat it.

• The Oil - Oil is basically the fluid to be transferred however the oil may generally be expected to be mixed with sea water, debris, and ice. Large pieces of debris and ice must, of course, be rejected at the pump suction, but it is desirable and even necessary for a pump used in the arctic to pass small pieces of ice. In a recent test several progressive cavity pumps were successful in passing pieces of ice with a 3/4" diameter. One double acting diaphram pump, specially designed to handle water/oil/solid mixtures in oil cleanup operations, is expected to pass solids with a 3" diameter. The results of the test of the diaphram pump are not available at this writing.

Transferring high viscosity oil is another problem that occurs during arctic cleanup operations. This problem is generally solved by using a pump suitable for transferring high viscosity fluids. In some cases, however, it may be desirable to attempt to reduce the viscosity of the oil. This can be accomplished by a number of methods.

First, a stirring propeller located ahead of the pump intake can reduce the apparent viscosity of the oil. This procedure is effective in improving the performance of a positive displacement pump used with very thick oils [12].

Oil viscosity can also be reduced by heating. This can be accomplished by the use of portable steam heating coils, electric heating coils, or even hot oil-spray heating [12]. In most cases, arctic oil recovery devices are mounted on small craft or employed at remote installations that are not likely to have access to steam. Electric heating of a recovery sump may be possible providing the power requirements are not high.

The viscosity of the collected product can also be reduced by diluting it with less viscous soluable fluid. This may be possible in some cases however it involves a logistics problem in obtaining the solvent and increasing the storage volume requirement for the recovered product.

Summary

A considerable amount of development and testing has been done to produce an effective arctic transfer system. Progress has been made to adapt and change system components so that they function in the cold arctic temperatures. Several tests have been conducted with pumps transferring highly viscous oil but there is less experience pumping the typical arctic oil/water/ice mixture. Generally the progressive cavity or positive displacement pumps are favored for this purpose, however even these are only capable of passing relatively small pieces of ice. A double acting hydraulically driven diaphram pump specifically designed for the oil/water/ice mixture has been developed and is being tested in Canada, however the results of these tests are not known as of this writing [15]. While much progress has been made on arctic transfer system components, a prototype system has not been developed. Development of a complete arctic transfer system remains a high priority R&D project.

Storage

Some form of temporary storage is often required when responding to an oil spill. The primary function of storage is usually as a buffer between mechanical recovery and disposal. In addition, smaller containers may be useful in ferrying oil from the skimmer to a tanker or a holding unit with a larger capacity. Means of storage include:

Natural Onshore or Ice Features - such as lakes, coves, or shorefast ice

Portable Floating Containers - both static and towable

Marine Vessels - such as ships and barges

Collapsible Land Based Storage - including pillow tanks

Other Land Based Storage - such as tank trucks and oil drums

Natural ice features may be used as short term storage. Oil could be pumped onto ice where it could be held by natural ice barriers or manmade barriers. Such barriers could be constructed by building a berm on shorefast ice and spraying it with water to form an ice lining. The use of shore features such as bays, beaches, or coves is likely only when there are no other near-term solutions. The use of natural onshore features such as natural reservoirs is only justified if the potential ecological threat of an uncontrolled spill far outweighs the local damage from the use of this storage technique.

Portable floating containers offer an excellent means of storage if the recovered oil is free of debris. Some of the floating containers which are towable are also air deployable, such as the type manufactured by Dunlop. The French Caiman is another towable container, but it has permanently pressurized floating tanks which make it non-air deployable. Another storage

device, called a donut, is a modified version of the U. S. Navy oil disposal raft. Table B-12 is a summary of floating containers which are currently available. These containers can be used in open water conditions in the arctic, but are vulnerable to puncture when used in the presence of ice.

Icebreaking tankers, which are presently being developed, could potentially be employed in the future for large volume aquatic oil spills in ice infested waters. Tank barges may also be useful in storing oil under certain conditions. Barges and ships have the added advantage of being useful as work platforms and can sometimes offer the additional capability of separating recovered oil and water.

Pillow tanks or water bags can be used for temporary storage. They have the advantage of being easily transportable and are commercially available. They can be placed on tugs and ships, or can be placed on large ice floes or shorefast ice. In addition, a pillow tank can be used on land and in a permafrost area since it has the ability to shift as the ground beneath thaws. Table B-13 is a list of representative commercial pillow tanks. Open topped containers listed in Table B-14 can be used on a stable platform. Portable swimming pools can also be used as temporary storage, providing an economical and easily transportable means of storage in remote areas.

Land-based tank trucks can also provide storage capacity. Tank trucks commonly used to transport petroleum products typically have a capacity of 1,000 to 6,500 gallons. Vacuum trucks typically have holding capacities varying from 1,000 to 4,500 gallons. Skid-mounted rigid wall tanks and oil drums could also be used as closed or open top containers. Permanent storage tanks located on shore could be used for holding the oil if a means of moving the oil to the tanks can be provided.

Disposal

Disposal of recovered oil can take place by either salvage or by incineration. Salvage is defined as the reuse of the recovered oil. Incineration refers to the disposal of the oil by burning with mechanical means. This does not include in situ burning which was discussed under recovery.

Salvage

There are a variety of ways to use oil recovered from a spill. Salvage of recovered oil in Alaska, however, presents special problems. Many of the secondary uses for recovered oil typically employed in the lower latitudes are often not feasible. Some of these include the use of oil for lower grade products such as asphalt, road oiling or weed control. Burial and land spreading are other methods of disposal which are sometimes successfully employed in lower latitudes but are generally not possible in Alaska.

One method of salvaging the oil would be to deliver the recovered product to a local refinery. However, the practicality of this method often limits its use. The logistics problems and the required additional oil processing make this alternative uneconomical most of the time.

The use of existing pipelines could provide another means of salvage. The recovered product, provided it is not considerably contaminated, could possibly be pumped into a pipeline. This would be feasible if a large volume of oil is being transported through this pipeline, and if the recovered oil is injected into the pipeline in small amounts. There may be little effect on the quality of the oil at the pipeline terminal.

Reinjection of the recovered oil into a well is another attractive alternative.

Incineration

Incineration, as opposed to in situ burning, involves some kind of recovery activity before disposal. The recovered oil is disposed of by some type of mechanical burning device. These devices include open flame burners, open pit burners and rotary kilns. All of these devices have the advantage of being transportable to the spill site, and could be used to burn the oil in an area adjacent to the storage containers.

The open flame burners have the potential for disposing of approximately 350 gal/min of oil at the spill site. These devices can presently be disassembled and transported in a C-130 aircraft. However, development is required to make them transportable by helicopter on pallets so they could be readily used on scene. The open flame burners can accept a product that contains small bits of rock, sand and debris, however, the limitation of the debris size has not been established. These devices can also handle a considerable amount of water mixed with the oil and still maintain a clean burn. The open flame burners may have problems in disposing of oil of high viscosity.

Rotary kiln burners can be used to burn oil mixed with nearly any kind of waste. The Environgenics Rotary Kiln Burner was designed to clean oil from beach sand and debris and could clean 20,000 lbs. of sand per hour containing 5,000 lbs. of oil. Although designed for mixtures of oil and sand, it appears that with slight modification it could be used for a mixture of oil, snow, ice and other debris.

Open pit burners can be used to dispose of large quantities of oil and oiled debris. A unit weighing between 20 to 30 tons could dispose of up to 1 ton per hour of oiled debris. These devices have the advantage of easy fuel handling, no requirements for skilled labor, low maintenance, and a low investment. There are presently no air transportable units available; however, the problem is under study by the Canadian Environmental Protection Service. Although the disposal rate of open pit burners is not as great as that of open flame burner, they could be effective in the arctic in disposing of high viscosity oil and oiled debris.

TABLE B-12 EVALUATION OF COLLAPSIBLE TOWABLE CONTAINERS FOR USE IN COLD REGIONS

Manufacturer	Container	Discription	Weight (lbs)	Volume (gal)	Min. Temp.	Comments Related to Cold Regions Use
Dunlop Rubber Co., Ltd. Cambridge Street Manchester, England	Dracones	Dynthetic rubber coated nylon fabric and end of strength and flexibility. Neoprene on the outside	2,328 to 9,520	13,500 to 290,750	--	Could be used on ice platform. Ice would prevent use in towing
Harding Pollution Control Corp. 12704-C N.E. 124th St. Kirkland, Washington 98033	Floating Oil/Water Separator (Donut)	Molded polyethylene, foam filled donut supporting a nylon fabric conical skirt	70	190	--	Oil/water mixture is pumped into separator; presumes ice is removed from mixture before pumping; device is a floating separator rather than a towable container.
Kepner Plastics Fabricators, Inc. 4221 Spencer St. 90503	Sea container	Keptex fabric and Kepylene foam	100 to 625	600 to 14,000	--	Limited use on ice floes
NEMO International 9, rue de Presbourg 75116 Paris R.C. Paris B 304454275	CAIMAN	Two flexible hydrocarbon containers form a floating catamaran	--	260; 15,900; 560,000	--	Suitable for use in open water, close spacing between tanks is likely to make it unsuitable for use in an ice field
Ocean Science and Engineering, Inc. 1601 Water Street Long Beach, CA 90802	Oil Storage Container	Nylon fabric covered with nitril rubber coating	2,470 to 4,570	21,000 to 126,000	--	Could be use on ice platforms

TABLE B-13 EVALUATION OF COLLAPSIBLE PILLOW BAGS FOR USE IN COLD CLIMATES

Manufacturer	Container	Description	Weight (lbs)	Volume (gal)	Min. Temp.	Comments Related to Cold Regions Use
B.F. Goodrich 430 S. Main St. Cohasset, Mass. 02025	Storitainers	High strength ends and fabrics coated with special rubber compounds	45 to 1,370	120 to 24,018	--	Made only for stationary storage. May have application on ice.
B.F. Goodrich 430 S. Main St. Cohasset, Mass. 02025	Mov-a-tainers	Stronger than storitainers	--	up to 5,000	--	When compared to Storitainers, appear to be better suited for cold region use because of added strength.
Goodyear Tire and Rubber Co. Industrial Products Div. Akron, Ohio 44316	Pillow Tank	-	-	1,000 to 65,000	--	--
Kepner Plastics 4221 Spencer St. Torrance, Calif.90503	Portable Storage Tank	Elastomeric coated nylon fabric	--	300 to 500	--	Suitable for storage if not susceptible to breakage due to cold temp.
Firestone Coated Fabrics Co. 2525 Firestone Blvd P.O. Box 1592 Southgate, Calif. 90280	Fabritank	Two-ply construction using Nitrile rubber coatings	--	5,000 to 50,000	-50°F	Have been in use in the Arctic since 1961. Very suitable for cold regions application.
Uniroyal Engineered System Dept. Mushawaka, Indiana 46544	Static Storage Tanks	Single-ply nylon fabric coated on both sides with polyurethane.	25 lbs to 1,519	250 to 100,000	-60°F	Have been used in the Arctic for storage. Very suitable for use in cold regions.

TABLE B-13 EVALUATION OF COLLAPSIBLE PILLOW BAGS FOR USE IN COLD CLIMATES (CONT'D)

Manufacturer	Container	Description	Weight (lbs)	Volume (gal)	Min. Temp.	Comments Related to Cold Regions Use
Dunlop Rubber Co., Ltd. Cambridge Street Manchester 1, England	Collapsible Containers	Double-ply fabric inside is coated with natural or synthetic rubber. Outside is polychloroprene.	--	60 to 60,000	--	Have been used in the Antarctic. Very suitable for use in cold regions.

TABLE B-14 EVALUATION OF PREFABRICATED OPEN TOPPED CONTAINERS FOR USE IN COLD REGIONS

Manufacturer	Container	Description	Weight	Volume (gal)	Min. Temp (°F)	Comments Related to Cold Regions
Banacudaverken York House, Empire Way Wembley, Middlesex England	Storage Reservoir	PVC-cloth, armoured and oil resistant	--	264 528 790	--	Applicable for land use, will shift with permafrost thaw.
Trelleborg Gummifabriks AB Trelleborg, Sweden	Portapool	Fabric is Polyester 1000 den PVC coating		2,600 800	--	Open topped but with a cover to guard against snow, suitable for use on permafrost.
Many	Swimming pools	---	--	315,000 is upper limit*	--	Inexpensive, readily available, will be suitable for use on permafrost.

* Reference report by Peterson [1] "Temporary Storage and Ultimate Disposal of Oil Recovered from Spills in Alaska."

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APPENDIX C

INVENTORY OF ALASKAN OIL SPILL ABATEMENT EQUIPMENT

A list of equipment currently located in the state of Alaska which has been designated for possible use in the event of an oil spill is presented on the following pages. A list of Alaskan organizations surveyed for the spill equipment inventory appears in Table C-1. This survey was conducted by Crowley Environmental Services Corporation, Anchorage under subcontract.

Information obtained by Crowley was reorganized to fit the format of the oil spill response system equipment lists. Therefore, manpower figures and miscellaneous hand tools have not been included. Also, items that could be used in more than one subsystem have only been listed once. As an example, helicopters and light aircraft have been listed in the surveillance category and not in the logistics or emergency evacuation categories. For the sake of completeness, the emergency evacuation subsystem has been expanded to include firefighting and safety equipment.

It should be noted that some of the equipment that is included may not be currently operational. Therefore, before relying on existing equipment for any contingency planning, a survey of the operational state of the equipment and the logistics requirements associated with its use should be made.

TABLE C-1. ORGANIZATIONS SURVEYED FOR THE ALASKA OIL SPILL EQUIPMENT INVENTORY LIST

Federal Agencies
- EPA
- Coast Guard
- Army
- Navy
- Air Force
- Corps of Engineers
- Bureau of Land Management (U.S.B.L.M.)
- Fish and Wildlife Service (U.S.F.&W.S.)
- Federal Aviation Administration
- USGS Oil and Gas Division
- USGS Water Resources Division
- Alaska Railroad
- Alaska Pipeline Office
- National Park Service
- Public Health Service
- Alaska Marine Highway

Alaska Department of Environmental Conservation
Alaska Department of Fish and Game
Alaskan Cities
Native Organizations
Volunteer Organizations CIRO-Cook Inlet Response Organization
CIRO Member Companies
- Amoco
- Arco
- Cook Inlet Pipeline Company
- Chevron
- Kenai Pipeline
- Nikiski Alaska Pipeline
- Marathon
- Mobil Oil
- Phillips
- Shell Oil
- Tesoro Alaskan
- Texaco
- Union

GOACO-Gulf of Alaska Cleanup Organization
Upper Cook Inlet Marine Committee
Crowley Environmental Services
R&S Pumping
Wade's Pollution Solution
Alaska Pollution Control
Alyeska Pipeline Service Company-Maintenance and Pump Stations
Alyeska Pipeline Service Company-Valdez Terminal

TABLE C-1. ORGANIZATIONS SURVEYED FOR THE ALASKA OIL SPILL EQUIPMENT INVENTORY LIST (CONTINUED)

Arco-Prudhoe Bay
BP Alaska-Prudhoe Bay
North Pole Refinery
Chevron Marketing
Other Oil Companies-Marketing
Arctic Lighterage-Kotzebue
Arctic Lighterage-Nome
Captain's Bay Tank Farm
Ketchikan Pulp
Alaska Lumber and Pulp
Mar Enterprises
Kenai Pumping
AAA Pumping
Alaska Commercial Company

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Surveillance	HH3F helicopter	3		Kodiak	U.S.C.G.
	HH52 helicopter	3		Kodiak	U.S.C.G.
	Aircraft	Unknown		Anchorage	U.S.B.S.F.& W.
	Aircraft	Unknown		Anchorage	N.M.F.S.
	Aircraft	Unknown		Anchorage	F.A.A.
	38' alum. survey boat	1	w/electronic positioning equipment	Anchorage	Army Corps of Engineers
	HH3F helicopter	4		Ketchikan	U.S.C.G.
	G-3 helicopter (contract) Beech-Twin (contract-24 hr)	1 1		Drift River (Cook Inlet)	Cook Inlet Pipeline Company
	Bell 204B helicopter	1		East Forelands (Cook Inlet)	Shell/Amoco
	Helicopter	1		Kenai	ARCO
	Gas and explosion meters	2		Anchorage	Alaska Pollution Control
	Hydrocarbon vapor detector	1		Prudhoe Bay	BP Alaska
	Beechcraft	1		Kotzebue or Nome	Arctic Lighterage Company
	MSA explosion meter	1	2A	Anchorage	Crowley Environmental Services

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Containment	Kepner boom (medium)	400'		Anchorage	U.S.C.G.
	Kepner compactible boom	400'			
	Goodyear boom (medium)	11,000'			
	Kepner compactible boom	200'		Valdez	U.S.C.G.
	Kepner boom	1,000'		Kodiak	U.S.C.G.
	Kepner compactible boom	400'			
	Material for log boom				
	USCG high seas boom	600'		Juneau	U.S.C.G.
	Kepner compactible boom	400'			
	Kepner boom (medium)	600'		Ketchikan	U.S.C.G.
	Kepner compactible boom	200'			
	Kepner compactible boom	300'		Yukatat	U.S.C.G.
	Sandbags	150,000		Anchorage	Army Corps of Engineers
	Vikoma Seapack	1	w/1,400' boom	Cook Inlet	C.I.R.O.
	Aqua Fence	1,000'			
	Boom	350'		Drift River (Cook Inlet)	Cook Inlet Pipeline Company
	Boom	800'			
	12" deep boom	300'		Swanson River Field	Chevron
	Whittaker Expandi boom	3	Model 4300 Seaboom (1,000'/pallet)		
	Acme 8" x 12" harbor boom	1,000'	on trailer	Yakutat	Gulf of Alaska Cleanup Organization
	Acme boom skimmer trailer	1,000'	8" x 12" boom Trailer (6' x 20')		
	Acme harbor boom 8" x 12"	1,000'	on skimmer trailer	Seaward	Gulf of Alaska Cleanup Organization

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Containment (continued)	Kepner compactible boom	2,000'	CSCBPHD1416DF, 14" x 16"		
	Kepner standard boom	1,100'	BHD812FF, 8" x 12"		
	Kepner boom lights	3			
	Kepner tow plates	2	(standard boom)		
	Tow line	1,000'		Anchorage	Crowley Environmental Services
	Kepner repair kit	4			
	Kepner compactible boom, 8" x 12"	900'	CSCBPHD812DF		
	Kepner fast-water compactible boom	1,000'	CSCBPHDN848DF		
	Tow plate assemblies	·4	compactible		
	8" x 12" Kepner boom	400'		Valdez	Crowley Environmental Services
	30" Bennett boom	500'		Anchorage	Alaska Pollution Control
	B.F. Goodrich Seaboom	4,880'	24" x 12" (installed)		
	American Marine curtain type	11,000'	14" x 16"		
	American Marine	3,000'	(Prince William Sound Special) 12" x 24"	Valdez Terminal	Alyeska Pipeline Service Company
	Aqua Fence	700'			
	Kepner Seacurtain	1,500'	6" x 12"		
	Vikoma Seapack	2	(1,600' boom)		
	Vikoma Seapack	3	(ordered)		
	Heavy duty Kepner boom	1,500'	14" x 24"	Prudhoe Bay	ARCO
	Heavy duty Kepner boom	2,000'	12" x 16"		
	Kepner boom	500'		Prudhoe Bay	BP Alaska
	Boom	500'		Dutch Harbor	
	Boom	250'		Seldovia	
	Boom	250'		Kodiak	Chevron, U.S.A.
	Boom	500'	(shared with Union Oil)	Ketchikan	
	Boom	500'	(shared with Union Oil)	Nome	

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Containment (continued)	Boom	500'	(shared with Chevron)	Juneau	Union Oil
	Kepner boom	400'	8" x 12"	Kotzebue	Arctic Lighterage Company
	Kepner boom	400'	8" x 12"	Nome	
	Kepner boom	1,000'	8" x 12"	Unalaska	Captain's Bay Tank Farm
	Log booms	40'		Ketchikan	Ketchikan Pulp Company
	Sea fence boom	800'	36" x 24"	Middle Ground Shoal, Cook Inlet	Shell

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery	Vac-U-Max skimmer	1			
	Sorbents	850	Particulate sorbent (lbs)	Anchorage	
		270	Conwed pads (bales)		
		10	Sorbent rolls		
	Sorbents	30	3M type 100 rools		
		61	3M type 156 bales	Valdez	
		31	3M type 126 sweeps		
	Vac-U-Max skimmer	1			
	Lockheed Type R2003 skimmer	1	(pontoon mounted, being delivered)		
	Sorbents	16	3M type 151 bales	Kodiak	
		14	3M type 156 bales		
		5	3M type 270 boom (cartons)		
	Oil skimmer	1	CCGD 17, #2124		U.S.C.G.
	Sorbents	300'	Sorbent boom		
		10	Conwed rolls		
		10	Oil Snare - boxes		
	Vac-U-Max skimmer	1			
	Lockheed Type 110 skimmer	1			
	Sorbents	10	3M type 157 bales	Juneau	
		30	3M type 100 rolls		
		600'	3M type 270 boom		
		6	3M type 240 pillows		
	Vac-U-Max skimmer	1			
	Oil skimmer USCD 17, #2124 with 300' of 4" hose	1			
	Sorbents	10	Sorbent rolls	Ketchikan	
		50	Sorbent pads (boxes)		
		15	Oil Snare (boxes)		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbent rolls	4		Yakatat	U.S.C.G.
	Sorbents	5 rolls		Whittier	U.S. Army
		5 rolls		Haines	
		5 rolls		Anchorage	
		15 rolls		Ft. Richardson	
		5 rolls		Tok	
		5 rolls		Ft. Wainwright	
		5 rolls		Ft. Greeley	
	Sorbents	1	Roll 3M Type 100 or Equivalent	Each FAA Field Station	F.A.A.
		1	Bale 3M Type 156 or Equivalent		
	Heavy duty liquid hand wringer	1			
	Sorbents		Small supply at each location	Anchorage, Seward, Whittier, Fairbanks, Healy	Alaska Railroad
	Barge mounted derric dredge	1		Anchorage	Army Corps of Engineers
	Sorbents	50'	3M Type 270 boom	Fairbanks	State of Alaska, Dept. of Environmental Conservation
		2	3M Type 100 rolls		
		1	3M Type 156 pads		
	Sorbents	150'	3M Type 270 boom	Valdez	
		8	3M Type 156 pads (bales)		
	Sorbents	1	Bale	Barrow	City of Barrow (Power Plant)
	Sorbents	2 2	Sorbent sweeps (boxes) 3M Type 270 boom (boxes)	Petersburg	City of Petersburg (Municipal Light and Power Utility)
	Sorbents	2	3M Type 100 sorbent rolls		City of Wrangell (Power Plant)

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbents	2	Sorbent pads (bales)		City of Seward (Harbor)
	Skimmers	1	Lockheed 3100 (3/78)		
		1	Cyclonet 050 (11/30/77)		
		1	Cyclonet 070 (4/78)		
		1	Cyclonet 120 (4/78)		
		1	Komara Miniskimmer and power pack		
		1	Mark II skimmer (weir-type catamaran)	Cook Inlet	C.I.R.O.
	Chemicals	90-55 gallon drums	Exxon Corexit 9527 dispersant		
		2	Helicopter spray applicators		
	Sorbents	12	3M Type 100 rolls		
		17	3M (18" x 24") pads (bales)	Anchorage	Chevron
		14	Conwed sorbent rolls		
	Sorbents	10	3M Type 156 pads (bales)		
		2	3M Type 100 rolls	Anchorage	Tesoro - Alaskan
		3	3M Type 270 booms (cartons)		
	Sorbents	1	3M Type 100 roll	Anchorage	Texaco
		2	3M Type 151 pads (bales)		
	Sorbents	2	2' x 2' pads (cartons)	Anchorage	Union Terminal and Asphalt
	Sorbents	1,600	Straw (bales)		
	Chemicals	5	Polycomplex A-11 (drums)		
		6	Chemical dispersant (drums)		
	Oil Mop skimmer	1		Drift River (Cook Inlet	Cook Inlet Pipeline Company
	Flotation skimmer with 120/gpm pump	1			

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbents	2	3M Type 100 rolls	Homer	Chevron
		1	3M pads (bales)		
	Sorbents	2	3M Type 157 sheets (bales)	Nikiski	Kenai Pipeline Company
		20	Sorbent Science 6'x1'x1-1/2"		
		200'	Grafco sorbent boom		
	Sorbents	5	3M pads (bales)	Nikiski	Tesero Alaskan Refinery
	Sorbents	2	2' x 2' pads (bales)	Nikiski	Union Oil
	Sorbents	2	(bales)	Nikiski	Nikiski Alaska Pipeline Company
	Sorbents	9	Sorbent (C) (18#/bag)	East Forlands (Cook Inlet)	Amoco
		2	Conwed pads (110/bale)		
		2	Conwed mats (6/box)		
	Chemicals	1	Polycomplex A-11 (drums)		
	Chemicals	1	Polycomplex A-11 (drums)	East Forlands (Cook Inlet)	Marathon
	Sorbents	3	Pads (boxes)	Granite Point Field, Cook Inlet	Mobil
	Chemicals	2	Polycomplex A-11 (drums)	Granite Point Field, Cook Inlet	Amoco
		2	Polycomplex A-11 (drums)		
	Chemicals	2	Polycomplex A-11 (drums)	Middle Ground Shoal, Cook Inlet	Amoco
		2	Polycomplex A-11 (drums)		
	Chemicals	1,000 lbs.	Sea beads	Middle Ground Shoal, Cook Inlet	Shell
	Sorbents	600	Sorbent pads	N. Cook Inlet Gas Field	Phillips
		400'	Sorbent sweep		
		200'	Sorbent booms		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Chemicals	1	Oil Herder (drum)	N. Cook Inlet Gas Field	Phillips
		1	Exxon 7664 (drum)		
	Chemicals	2	Dispersant (drums)	Truding Bay Field, Cook Inlet	Texaco
	Sorbents	20	3M Type 156 pads (bales)	Kenai Gas Field	Union Oil
		30	3M Type 151 pads (bales)		
		24	3M Type 270 booms (cartons)		
		4	3M Type 100 rolls		
	Sorbents	52	Straw (bales)	Swanson River Field (Cook Inlet)	Chevron
		25	Excelsior (bales)		
		50	Oil Blotter (bags)		
		400	Sorbent Type "C" (bags)		
	Chemicals	1	Slickoff (drum)		
	Sorbents	1	3M Type 100 roll	Anchorage Airport	Shell Oil
	Olea III skimmer	1			
	Sorbents	3	3M Type 270 booms (cartons)	Kenai	ARCO
		8	3M Type 151 pads (bales)		
		2	3M Type 100 rolls		
	Chemicals	2	Polycomplex A-11 (drums)	Kikiski	Marathon
	Sorbents	8	3M Type 151 pads (bales)	Kenai	Phillips LNG
		9	3M Type 126 sweeps (cartons)		
		17	3M Type 270 booms (cartons)		
		16	3M Type 100 rolls		
	Chemicals	2	Oil Herder		
		2	Exxon 7664 dispersant		
	Sorbents	41	3M Type 100 rolls	Yahutat	Gulf of Alaska Cleanup Organization
		14	3M Type 156 bales		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbents	85	3M Type 270 boom (cartons)		
		5	3M Type 240 pillows (bales		
		2	bales 3M pads		
		2	boxes 3M boom		
	Skimmers	2	Komara Miniskimmer		
		1	Acme skimmer 39TG-4 with 300' of 4" floating hose and fittings	Yakutat	Gulf of Alaska Cleanup Organization
	Chemicals	180	Exxon 9527 dispersant (55-gallon drums)		
		5	Exxon OC-5 collectant (55-gallon drums)		
		2	Helicopter spray units (600-gallon capacity)		
	Sorbents	16	3M Type 151 pads (bales)		
		7	3M Type 270 booms (cartons)	Granite Point	ARCO
	Oil skimmer with 3" hose (60')	1			
	Sorbents	1-3/4	Boxes sorbent pads	Granite Point	Mobil
	Skimmer	1	Acme 39TG-4, hose, fittings, and sorbent		
	Sorbents	50	Conwed blankets	Seward	Gulf of Alaska Cleanup Organization
		23	Conwed bales		
		1	Conwed pillows (bale)		
		50	3M Type 270 boom (cartons)		
		4	3M Type 126 sweeps		
		4	3M Type 156 pads (bale)		
	Chemicals	2	Hand-type sprayers (4-gallon)		
	Oil Mop oil/water separator, 10 gpm	1	R-10	Anchorage	Crowley Environmantal Services

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Kepner floating separator	1	Positioning Wand		
	CES Mfg. Oleo III skimmer	3			
	CES Mfg. SLURP skimmer	1			
	Lockheed disc skimmer	1	110F		
	Vau-U-Max	1	TK1N		
	Vac-U-Max (modified TK1N)	2	TK31N		
	Oil Mop MK II-4E, 100' OCW 3-4 rope mop, TP-12 pulley	1	MK II-4F		
	Oil Mop MK II-4H	1	MK II-4H		
	36" MANTA skimmer, rigid	1			
	48" MANTA skimmer, flexible	1			
	Skimmer duckbill (high capacity adjustable head)	1			
	Sorbent	Large Inventory varying with sales	Dow Imbiber beads		
			Dow Imbiber packets		
			Sorb-Oil boom with connectors, 8" x 20' polysleeved		
		"	Sorb-Oil chips 20-lb carton		
		"	3M Type 100 rolls, 3/8" x 36" x 150'		
		"	3M Type 126 sweeps, 3/8" x 22" x 100'	Anchorage	Crowley Environmental Services
		"	3M Type 151 sheets, 3/16" x 18" x 18"		
		"	3M Type 156 sheets, 3/8" x 18" x 18"		
		"	3M Type 157 sheets, 3/8" x 36" x 36"		
		"	3M Type 240 pillow, 5" x 14" x 25"		
		"	3M Type 270 booms with connectors, 8" x 10'		
	Sorbents	1	20' cargo van with inventory of assorted sorbents	Homer	

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbents	1	20' cargo van with inventory of sorbents	Kodiak	
	Sorbents	1	20' cargo van with inventory of assorted sorbents	Valdez	Crowley Environmental Services
	Sorbent		Inventory of sorbent material	Seward	
	Sorbent		Inventory of sorbent material	Juneau	
	Sorbents	30	3M Type 100 rolls	Juneau	R & S Pumping
		30	3M Type 126 sweeps		
		30	3M Type 156 bales		
		10	3M Type 240 pillows (cases)		
		20	3M Type 270 boom (cases)		
		10	Sorb-Oil swabs (cases)		
	Sorbents	1,000'	3M Type 270 boom	Kenai	Wade's Oil Field Service
		Supply	3M Type 156 bales		
		Supply	3M Type 157 bales		
	Chemicals	1	Dispersant (NACOL) drums		
	Sorbents	Large Supply	Sorbent boom	Anchorage	Alaska Pollution Control
		Large Supply	Sorbent pads		
	Chemicals	2	Oil dispersant (drums)		
	Skimmers	1	Marco Class VII	Valdez	Alyeska Pipeline Service Company
		1	Marco Class V		
		1	Marco Class I		
		1	*Vikoma Seaskimmer* (disc)		
		2	Acme		
		3	Komara Miniskimmer		
		4	SLURP		
		2	COPE		
		2	Slickskim Manta Ray		
		5	Vac-U-Max (55-2N) with attachments		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbents	5,000'	Boom	Valdez	Alyeska Pipeline Service Company
		150	Blankets or rolls		
		100	Bales sorbent sheets		
	Skimmers	1	FS300A floating saucer skimmer with gas engine and hoses	Prudhoe Bay	ARCO
		2	Oleo III floating skimmer heads		
		1	Komara Miniskimmer and power pack		
		1	Oil Mop MKII-4VE with 200' 4-6 rope mop and 2 TP-16 tail pulleys		
	Sorbents	144'	Booms		
		40	Blankets or rolls (150'/bale) pads		
	Skimmers	1	Komara Miniskimmer with pump & accessories	Prudhoe Bay	BP Alaska
		1	Komara Miniskimmer with pump (ordered)		
		1	Oil Mop MK I-4 with rope & pulleys		
		1	Oil Mop MK II-9 with 500' rope (ordered)		
		1	Vac-U-Max		
		50'	2" suction hose		
	Sorbents	480'	Boom		
		40	Pads (bales)		
	Sorbents	5	Sorbent pads (bales)	North Pole	North Pole Refinery
	Sorbent rolls	2		Cordova	Chevron U.S.A.
	Sorbent bales	1			

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbent rolls	7		Valdez	
	Sorbent bales	2			
	Sorbent rolls	2		Seward	
	Sorbent bales	1			
	Sorbent rolls	2		Seldovia	
	Sorbent bales	1			
	Sorbent rolls	2		Kodiak	
	Sorbent bales	1			
	Sorbent rolls	2		Cold Bay	
	Sorbent bales	1			
	Sorbent rolls	2		Dutch Harbor	
	Sorbent bales	1			
	Sorbent rolls	2		Fairbanks	Chevron U.S.A.
	Sorbent bales	1			
	Sorbent rolls	2		Fort Yukon	
	Sorbent bales	1			
	Sorbent rolls	38		Ketchikan	
	Sorbent bales	112			
	Sorbent rolls	41		Juneau	
	Sorbent bales	118			
	Sorbent rolls	2		Skagway	
	Sorbent bales	1			
	Sorbent rolls	2		Petersburg	
	Sorbent bales	1			
	Sorbent rolls	2		Naknek	
	Sorbent bales	1			

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbent rolls	2		Dillingham	
	Sorbent bales	1			
	Sorbent rolls	2		Bethel	
	Sorbent bales	1			
	Sorbent rolls	2		Platinum	
	Sorbent bales	1			
	Sorbent rolls	2		St. Michael	
	Sorbent bales	1			
	Sorbent rolls	2		Nome	
	Sorbent bales	1			
	Sorbent rolls	2		Kotzebue	
	Sorbent bales	1			
	Sorbent rolls	2		Delina	Chevron U.S.A.
	Sorbent bales	1			
	Sorbent rolls	2		Nenana	
	Sorbent bales	2			
	Sorbent rolls	2		Wrangell	
	Sorbent bales	1			
	Sorbent rolls	2		Pelican	
	Sorbent bales	1			
	Sorbent rolls	2		Sitka	
	Sorbent bales	1			
	Sorbent rolls	2		Hoonah	
	Sorbent bales	1			
	Sorbent rolls	2		Angoon	
	Sorbent bales	1			

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Recovery (continued)	Sorbent rolls	2		Yakutat	Chevron U.S.A.
	Sorbent bales	2			
	Sorbent rolls	2		Haines	
	Sorbent bales	1			
	Sorbent pads (bales)	6		Fairbanks	Mobil Oil
	Sorbent rolls	2			
	Sorbent pads (bales)	6		Valdez	
	Sorbent rolls	2			
	Sorbents	20' van with	assortment of 3M rolls & pads	Kotzebue	Arctic Lighterage Company
	Sorbents	20' van with	assortment of 3M rolls & pads	Nome	
	Sorbents	5	Sort-Oil boom (40' carton)	Unalaska	Captain's Bay Tank Farm
		20	3M Type 156 pads (bales)		
	Sorbents	800'	Boom	Ketchikan	Ketchikan Pulp Company
		25	3M Type 156 bales		
		20	3M Type 270 cartons		
		10	3M Type 240 pillows (cases)		
		30	3M Type 156 bales		
		100'	Sorbent boom		
	Sorbents	1,000'	Sorbent boom	Sitka	Alaska Lumber and Pulp Company
		25	Conwed rolls		
		45	Conwed bales		
	Small skimmer head	1		Soldotna	Mar Enterprises
	Sorbents	2	Sorbent pads (bales)	McGrath	Alaska Commercial Company

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Storage	Portable tank	1	5,000-gallon	Kodiak	U.S.C.G.
	Portable tank	1	500-gallon		
	Portable tank	1	250-gallon		
	Collapsible bladder	8	500-gallon	Juneau	
	Collapsible bladder	7	500-gallon	Ketchikan	
	Storage drum	Unknown	55-gallon	All bases	U.S.A.F.
	Flat bottom barge	1	120' x 35'	Anchorage	Army Corps of Engineers
	Barge	1	landing craft type 45' equipt to transport fuel, oil & dry cargo	Naknek Lake	National Park Service
	300-gallon trailer-mounted tank	1		Drift River	Cook Inlet Pipeline Company
	90,000-bbl ballast tank	1			
	Crude storage tanks				
	Ballast tank	1	130,000-bbl	Nikiski	Kenai Pipeline Company
	Ballast tank	1	20,000-bbl		
	Tanks	3	with total 33,000-bbl capacity	Granite Point	Mobile
	Bladder tanks	2	35,000-gallon (in use)	Kenai Gas Field	Union Oil
	Bladder tank	1	50,000-gallon (in use)		
	Baker tank	6	500-bbl	Swanson River Field	Chevron
	Tank (tank farm)	1	20,000-bbl	Anchorage Airport	Shell Oil
	Tank (skid-mounted)	4	500-barrel	Kenai	ARCO
	Bladder tank	2	25,000-gallon	Kenai	Phillips LNG
	Bladder tank	1	50,000-gallon		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Storage (continued)	Towable bladder	2	Dunlop 2,000-gallon	Yakutat	Gulf of Alaska Cleanup Organization
	Pillow tank	1	Firestone 25,000-gallon		
	Towable seabags with fittings	1	Kepner 600-gallon	Anchorage	Crowley Environmental Services
		2	Kepner 300-gallon		
	Bladder tank	3	Uniroyal Unithane 10,000-gallon		
	Tank	1	Greer metal 10,000-gallon		
	Bladder tank	1	Uniroyal 20,000-gallon		
		1	Goodyear 20,000-gallon		
		1	Uniroyal 50,000-gallon		
		1	Goodyear 6,000-gallon		
		1	Goodyear 1,000-gallon		
	Seal Drum	2	Uniroyal 500-gallon		
	Drums	20	55-gallon	*Juneau*	R & S *Pumping*
	Portable tank	2	3,000-gallon	Kenai	Wade's Oil Field Service
	Portable tank	1	500-gallon		
	Drums	Supply	55-gallon		
	Waste oil storage capacity		200,000-gallon	Anchorage	Alaska Pollution Control
	55-gallon containers	10	modified for lifting with crane		
	Pillow tank, towable	5	500-gallon	Valdez	Alyeska Pipeline Service Company
	Pillow tank	5	1,000-gallon		
	Fuel cans	24	5-gallon		
	Drums	50	55-gallon		
	Shafer storage barge	1	(5,300-bbl, contracted)		
	Steel tanks	3	6,700-bbl capacity bolted *(dismantled)*	Prudhoe Bay	ARCO

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Storage *(continued)*	Bladders	2	1,000-gallon	Prudhoe Bay	ARCO
	Pillow tank	28	100,000-gallon	Prudhoe Bay	BP Alaska
	Pillow tank	3	50,000-gallon		
	Tank (storage)	Variable	Variable	North Pole	North Pole Refinery
	Portable skid-mounted tank	1	5,000-gallon	Kotzebue	Arctic Lighterage Company
	Portable skid-mounted tank	1	23,000-gallon		
	Portable skid-mounted tank	1	4,000-gallon		
	Portable tank	2	5,000-gallon	Nome	
	Drums	Quantity	55-gallon	McGrath	Alaska Commercial Company

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Transfer	Adapts	1		Anchorage	U.S.C.G.
	Adapts	1		Kodiak	U.S.C.G.
	Air deployable SAR	1	150-gpm	Kodiak	U.S.C.G.
	Wheeled pump	1	2" portable	Kodiak	U.S.C.G.
	Wheeled pump	1	3" portable	Kodiak	U.S.C.G.
	Vacuum truck	1	2,000-gallon	Kodiak	U.S.C.G.
	Pumps	2	Homelite P-250 portable	Ketchikan	U.S.C.G.
		2	Homelite P-120 portable	Ketchikan	U.S.C.G.
	Separators	1	Fixed oil/water separator	Ketchikan	U.S.C.G.
	Hot tap pump	1	For lightering overturned tank cars	Anchorage	Alaska Railroad
	Pumps	1	3" portable	Anchorage	Chevron
	Pumps	1	Homelite	Anchorage	Texaco
		1	Gorman-Rupp	Anchorage	Texaco
	Hoses	3	2" (50 feet)	Anchorage	Texaco
	Pumps	2	Homelite 3"	Anchorage	Union Terminal and Asphalt
	Tank truck	3	4,000-gallon	Anchorage	Union Terminal and Asphalt
	Pumps	1	Centrifugal 2,000-bph @ 30 psi CW	Drift River	Cook Inlet Pipeline Company
		1	Rice 3" trash pump	Drift River	Cook Inlet Pipeline Company
		1	Barnes 4" trash pump	Drift River	Cook Inlet Pipeline Company
		3	50-70 gpm centrifugal	Drift River	Cook Inlet Pipeline Company
		1	Caterpillar diesel-drive (skid-mounted)	Drift River	Cook Inlet Pipeline Company
	Vacuum tanks with pump	1	(trailer-mounted)	Drift River	Cook Inlet Pipeline Company

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Transfer (continued)	Pumps	1	600-gpm gas diaphragm pump 2" suction gas-driven		
		1	Homelite	Nikiski	Chevron
	Firehose	200'	2-1/2"		
	Vacuum truck	1	40-bbl	Nikiski	Tesoro-Alaskan
	Tank trucks	4		Nikiski	Union Oil
	Pumps	1	Marlow Moall 405 4" pump, gas with 25-ft. hose	Granite Point	ARCO
	Pumps	1	3" gas pump	Granite Point	Mobil
		1	2" gas pump		
	Pumps	1	150 hp centrifugal pump on skids	Middle Ground Shoal	Shell
	Hose	200'	2" Hi. P. hose		
		100'	4" Low P. hose		
	Pumps	1	Briggs & Stratton 3" diaphragm with 3.5 hp	No. Cook Inlet	Phillips
	Hose	200'	3" hose		
	Vacuum truck	2		Swanson River Field	Chevron
	Pumps	2	3" Homelite pump		
	Hoses	400'	2" hose	Anchorage Airport	Shell
	Pumps and Hoses	1	4" centrifugal with 35 hp on 2-wheel trailer	Kenai	Phillips LNG
		300'	3" hose		
	Pumps	1	Homelite 2" diaphragm, 30 gpm Stanley 2-1/2" submersible dewatering, 111DP2-1	Anchorage	Crowley Environmental Services
		2	500 gpm, SM22		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Transfer (continued)	Pumps	1	Homelite 2" centrifugal, 150 gpm, 111S2-1	Anchorage	Crowley Environmental Services
		1	Homelite 2" trash pump, 195 gpm, 121TP2-1		
		1	Homelite 2-1/2" high pressure 115P2-1/2"-1A		
		1	Homelite 4" trash pump, 610 gpm, 160TP4-1		
		2	Homelite 3" trash pump, 300 gpm, 120S3-1		
		1	Homelite 3" trash pump, 120TP3-1A, 385 gpm		
		1	Gorman Rupp 3" lister diesel, Centrifugal, 320 gpm		
		1	Gorman Rupp 4" lister diesel, 13A2-LR1, Centrifugal, 600 gpm, 14A2-SR27		
		2	Edson 2" hand diaphragms		
	Hoses	2	4" x 50' discharge		
		4	2" x 25' suction		
		4	2" x 20' suction		
		10	3" x 20' suction		
		14	3" x 50' discharge		
		13	4" x 20' suction		
		-	1-1/2" x 100' fire hose		
		2	2" x 50' discharge		
		-	1-1/2" x 20' fire hose		
	Tank truck	1	GMC 3,000-gallon		
	Vacuum truck	1	Kenworth 3,800-gallon		
	Tank truck	1	1,600-gallon	Juneau	R & S Pumping
	Pumps	2	3" diaphragm with 400' hose		
		1	1-1/2" centrifugal pump and 200' hose		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Transfer (continued)	Pumps	2	3" electric submersible	Kenai	Wade's Oil Field Service
		5	4" electric submersible		
		2	3" gas trash		
		1	3" pneumatic		
	Hoses		Hoses for all pumps		
	Vacuum trucks	2		Anchorage	Alaska Pollution Control
	Pumps	2	2" pumps and hoses		
		2	3" pumps and hoses		
	Pumps	2	2" diaphragm pump, diesel	Valdez	Alyeska Pipeline Service Company
		2	4" diaphragm pump, diesel		
		2	2" hand pump		
	Hose	300'	2" suction		
		300'	2" discharge		
	Vacuum Trucks	1	Vac-All, 2,000-gallon truck		
		1	Trans Vac system (skid-mounted)		
	Pumps	2	88-h.p. submersible, 440- or 550-volt (can pump 150,000 bbls/day), complete with cable and 100' of 10" flexible hose and flanges	Prudhoe Bay	ARCO
		1	Suction pump (100,000 bbls/day)		
		1	Suction pump (80,000 bbls/day		
		2	3" electric diaphragm pump with suction and discharge hose		
	Vacuum trucks	3			
	Pumps	2	3" Homelite trash pumps and hoses	Prudhoe Bay	BP Alaska

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Transfer (continued)	Tank trucks	3		Kotzebue	Arctic Lighterage Company
	Vacuum truck	1	750-gallon		
	Pumps	3	4" diesel and hoses		
		2	3" Homelite trash		
		2	1-1/2" Homelite trash		
	Tank truck	1		Nome	Arctic Lighterage Company
	Pumps	3	4" diesel and hoses		
		2	3" Homelite trash		
		2	1-1/2" Homelite trash		
	Tank truck	1	Single axle	Ketchikan	Ketchikan Pulp Company
	Vacuum trucks	3		Soldotna	MAR Enterprises
	Pumps	2	Vacuum pump		
	Vacuum tru[illegible]	3	(septic tank)	Kenai	Kenai Pumping
	Pumps	2	High pressure wash truck	Kenai	AAA Pumping
	Vacuum trucks	2	85-bbl and 75-bbl		
	Pumps	2	2" suction pumps and hoses	McGrath	Alaskan Commercial Company
Disposal	Hazardous waste landfill	40 acres		Kenai	Kenai Peninsula Borough
	Rerefining capabilities			North Pole	North Pole Refinery
	Waste oil mixed with log fuel and burned in power boiler			Ketchikan	Ketchikan Pulp Company
	Waste oil burned in power boiler with log fuel				Alaska Lumber and Pump Company

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Disposal (continued)	Incinerator	1		Granite Point	Mobile
Logistics	Support Equipment	1	Portable 35-cfm air compressor	Anchorage	U.S.C.G.
	Vessels	1	40' crash boat		
		1	CGC Sedge (180')		
		60	Crew complement		
		200'	Kepner compactible boom		
		2	Sorbent rolls		
		1	Oil spill containment kit (personnel gear)		
		1	Sample kit		
	Support Equipment	5	Sample kits	Valdez	
	Vessels	1	23' UTL patrol boat with trailer		
		1	65' tug (BITT)		
		2	Sorbent rolls		
		6	Crew complement		
		1	CGC Sweet Briar (180')	Cordova	
		2	Sorbent rolls		
		1	Oil spill containment kit		
		60	Crew complement		
		1	CGC Jellison (95')	Seward	
		2	Sorbent rolls		
		1	Oil spill containment kit		
		14	Crew complement		
		1	8' PUNT	Kodiak	
	Support Equipment	2	Portable air compressors 120-psi, 3,000-lb		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vessels	1	13' Boston Whaler (20 hp, outboard)	Kodiak	
		1	CGC *Citrus* (180')		
		2	Sorbent rolls		
		1	Oil spill containment kit		
		60	Crew complement		
		1	CGC *Storis* (230')		
		2	Sorbent rolls		
		1	Oil spill containment kit		
		80	Crew complement		
		1	CGC *Confidence* (210')		
		2	Sorbent rolls		
		1	Oil spill containment kit		
		80	Crew complement		
		1	CGC *Ironwood* (180')	Adak	
		2	Sorbent rolls		
		1	Oil spill containment kit		
		60	Crew complement		
	Aircraft	4	C-130 fixed wing	Kodiak	
	Support Equipment	1	Portable air compressor, 35-cfm	Juneau	
		10	Sample kits		
	Support Equipment	1	Portable air compressor	Juneau	U.S.C.G.
		1	Sample kit		
	Vessels	1	CGC *Cape Coral* (95')		
		2	Sorbent rolls		
		2	Oil spill containment kit		
		14	Crew complement		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)		1 2 1 60	CGC Planetree (k80') Sorbent rolls Oil spill containment kit Crew complement	Juneau	
		1 2 1 60	CGC Clover (180') Sorbent rolls Oil spill containment kit Crew complement	Sitka	
		1 2 1 14	CGC Cape Henlopen (95') Sorbent rolls Oil spill containment kit Crew complement	Petersburg	
		1 2 1 5	CGC Elderberry (65') Sorbent rolls Oil spill containment kit Crew complement	Petersburg	
	Support Equipment	2	Sample kits	Ketchikan	
	Vessels	1	12' Zodiak skiff	Ketchikan	U.S.C.G.
		1	16' Aluminum skiff 1/2" mooring cables & sinkers		
		1 2 1 14	CGC Cape Romain (95') Sorbent rolls Oil spill containment kit Crew complement		
		1 2 1 60	CGC Laurel (180') Sorbent rolls Oil spill containment kit Crew complement		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)		1	14' Boston Whaler with 25 hp outboard	Yakutat	
		1	21' Coast Guard SKB with 70 hp outboard		
	Communications Equipment Mobile or portable communications equipment with operators. Fixed base stations are available at Nome, Dillingham, Amchitka, Anchorage Snettisham, and Juneau on single sideband, AM compatible. One mobile unit is mounted in a vehicle at Anchorage. In the event of an emergency, operators will be available.				Army Corps of Engineers
	The Alaska District maintains an organized forest fire fighting team. During the summer, several hundred men are employed in this activity. They are supported by aircraft, complete mobile field camps radios, heavy equipment, etc. During the winter, standby village crews, approximately 21 men per village, are available. In addition, aircraft deployable smoke jumpers are stationed at Fairbanks and Anchorage. Other stations are Glenallen, Ft. Yukon, and McGrath. U. S. Bureau of Land Management (BLM) can provide contingent upon an availability basis, fire fighters who can supplement any work force mobilized for a spill situation. This could include surveillance equipment, and manpower transportation and all the field support necessary for extended field duty. Additional manpower can be flown up from Missoula, Montana if required.				U.S.B.L.M.
	The Fish and Wildlife Service has aircraft, both land and amphibian, which could be called upon for air support in a spill situation. The aircraft are based at the Lake Hood Airport, Anchorage. These aircraft are used to support FWS field work and use is contingent on availability. A radio network is maintained for air-ground communications and is compatible with BLM. Stations are located at Anchorage, Fairbanks, Kenai, Kodiak, King Salmon, Bethel, and Kotzebue. Aircraft are permanently based at Refuge Headquarters. Mobilization of this support equipment is accomplished by calling EPA, AOO, Anchorage, who, in turn, will contact the Aircraft Supervisor, BSF&W, Anchorage.				U.S.B.S.F.&W.

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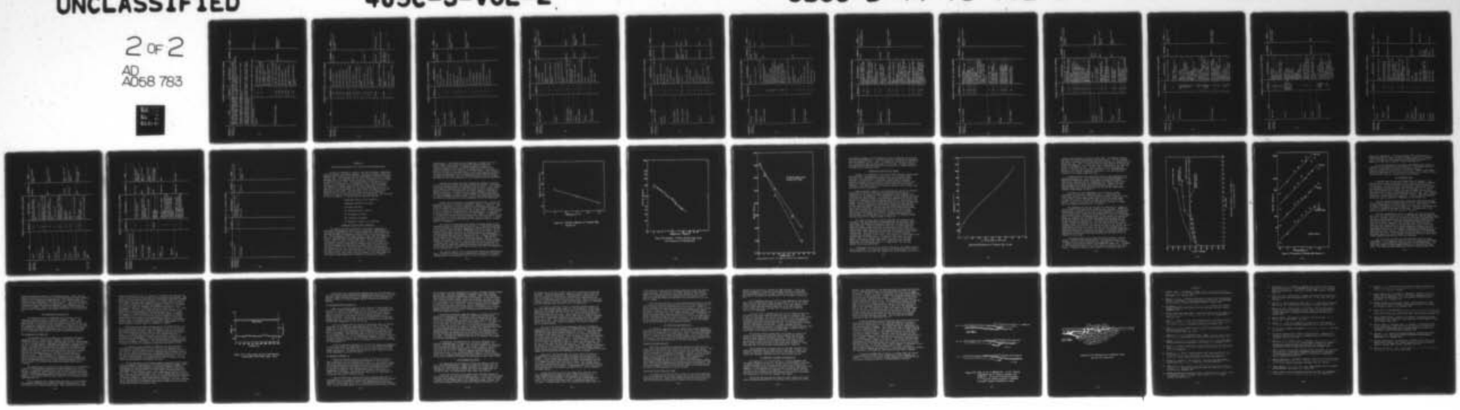

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INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	NMFS operated a laboratory at Auke Bay near Juneau and Kasitsna Bay near Homer. Small craft could be made available if a spill were located near any of these two stations contingent on availability. A station at Kodiak has two vessels, a 100 foot and a 65 foot, which could be used contingent on availability. Aircraft are pooled with the BSF&W facilities at Anchorage and could be made available through the Aircraft Supervisor. An 80 foot power barge, stationed in Juneau, could be manned and mobilized to conduct estuarine or near-shore biological studies or could be used to deploy containment and cleanup equipment. A field station at Little Fort Walter is open during the summer and several light skiffs are available.				N.M.F.S.
	Vessels	1	24' Aluminum survey boat		
		1	12" Hydraulic pipeline dredge		
		1	45' Tugboat, shallow draft, 500 hp twin screw		
		1	45' Tugboat, shallow draft, 200 hp single screw		
		1	8" Hydraulic pipeline dredge		
	Communications Equipment	1 ea.	1,000 watt HF base station	Anchorage	Army Corps of Engineers
		2 ea.	100 watt HF base stations		
		1 ea.	100 watt HF mobile		
		1 ea.	100 watt VHF-FM base		
		20 ea.	2 watt--6 watt VHF-FM portables		
		3 ea.	1 watt/25 watt marine VHF mobiles		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)		1 ea.	100 watt HF base	Fairbanks	U.S. Army Corps of Engineers
		1 ea.	100 watt HF mobile		
		1 ea.	100 watt VHF-FM base		
		1 ea.	30 watt VHF-FM base		
		2 ea.	30 watt VHF-FM mobile		
		10 ea.	2-10 watt VHF-FM portables		
		1 ea.	100 watt HF base	Nome	
		4 ea.	10 watt VHF-FM portables		
		3 ea.	1 watt/25 watt marine VHF mobiles		
		1 ea.	100 watt HF base	Dillingham	
		4 ea.	10 watt VHF-FM portables		
		2 ea.	1 watt/25 watt marine VHF mobiles		
	Railroad Cars	Unknown		Anchorage	Alaska Railroad
	Vessels	1	Ship "Nunatak", 65' passenger and cargo	Bartlett Cove	National Park Service
	Heavy Equipment	Unknown	Graders, bulldozers, & end loaders	Mt. McKinley Park Hdqtrs.	
	Vessels	1	Zodiac (11/30/77*)	Cook Inlet	C.I.R.O.
		1	Union boat (30' x 17' tuna purse seiner)		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vehicles	1	1/2-ton pickup	Anchorage	Chevron
		1	36-Drum package truck		
	Heavy Equipment	2	Forklifts		
		1	Tractor with scoop		
	Support Equipment	1	Scott Air Pack	Anchorage	Union Terminal and Asphalt
	Vehicles	2	Transport vans		
		1	Package van		
		1	Pickup with snow blade		
	Heavy Equipment	2	Forklifts		
	Support Equipment	1	Air pump	Drift River	Cook Inlet Pipeline Company
		1	Joy 125 compressor		
		2	50-kw generator		
		1	135-kw generator		
		1	30-kw generator		
		2	1.5-kw portable generators		
	Vehicles	2	2-ton truck		
		1	Gallion motorgrader		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Heavy Equipment	1	D-8 bulldozer	Drift River	Cook Inlet Pipeline Company
		1	D-6 bulldozer		
		1	Caterpillar 950 front-end loader		
		1	Case front-end loader and forklift		
	Vessels	1	14' boat with 25 hp motor		
		1	16' boat with 35 hp motor		
		1	26' Bartend CW with 170 hp diesel		
	Support Equipment	2	110-volt portable lightstands	Nikiski	Chevron
	Heavy Equipment	1	Ford Tractor with 1-1/2 ton front-end loader		
	Vessels	1	20' inboard motor boat	Nikiski	Kenai Pipeline Company
	Heavy Equipment	1	Small crane		
		1	Tractor with front-end loader		
	Vehicles	2	Pickup	Nikiski	Tesoro-Alaskan
		1	Truck		
	Heavy Equipment	1	Front-end loader		
		1	Road grader		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Support Equipment	1	Living quarters (for 10 men)	Granite Point	
		1	Wheelbarrow		
	Vessels	1	20' Bartender rescue boat		
	Vehicles	1	Motor grader	East Forelands	Mobil
		1	4-wheel drive pickup		
		1	4 x 4 Dodge wagon		
	Heavy Equipment	1	Backhoe		
	Support Equipment	4	3.4 kw portable gas generators	MacArthur R. Field	Union
	Support Equipment	300 sq. ft.	Astroturf	Middle Ground School	Shell
	Heavy Equipment	1	Motor patrol grader	Trading Bay	Marathon
		1	Front-end loader		
		1	Forklift		
		1	D-7 Caterpillar		
	Vessels	1	Bartender	Trading Bay	Union
		1	22' boat with 410 cu. in. diesel		
		1	Bruckers 40 hp diesel		
	Vessels	1	21' I/O	No. Cook Inlet	Phillips

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vehicles	1	Steam truck	Swanson River Field	Chevron
	Support Equipment	1	Small lighting plant	Anchorage Airport	Shell
	Vessels	1	17' Outboard with 33 hp motor		
	Support Equipment	1	Skid-mounted contingency building containing:	Kenai	Arco
		19	Garden rakes		
		21	Pitch forks		
		32	Round point shovels		
		24	Square point shovels		
		10	Galvanized 3-gal. buckets		
		2	Pneumatic tired wheel barrow		
		12	3-cell explosion-proof flashlight w/batteries		
		2	600' coil 1/2" nylon rope		
		25	3M Type 156 pags (bales)		
		27	3M Type 270 booms (ctns)		
		2	3M Type 100 rolls		
		1	7.5 kw generator, gas, skid-mounted		
	Support Equipment	2	Portable lights with generators	Kenai	Phillips LNG
		6	Spades		
		6	Pitchforks		
	Heavy Equipment	1	Case 530 farm tractor		
		1	Case 580 front-end loader		
		1	Crawler tractor		
		1	John Deere 350		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Support Equipment	1	3-kw electric generator--portable, gas powered with:	Yakutat	Gulf of Alaska Cleanup Organization
		2	Floodlight on tripod (1,000 watt)		
		75	Electrical lead		
		2	Skid-mounted diesel-hydraulic power unit, hoses & storage container for Komara Mini-skimmers		
		1	Vacuum sweeper, tank type (Whittaker boom)		
	Communications	12	Radio, UFH-FM, hand-held, Motorola MX330, Type 44, battery-operated with chargers	Anchorage	
	Support Equipment	2	MSA portable air pack	Anchorage	Crowley Environmental Services
		1	Home chain saw, 36" and 48" bars		
		2	Homelite 2.75-kw generators (gas)		
		1	Steamcleaner		
		1	Stanley gasoline hydraulic system (includes 2, 10-gpm systems @ 2,000 psi)		
		1	Diesel hydraulic system power pack, 10-gpm with (6) 1/2" x 50' and (6) 3/4" x 50' hydraulic hoses		
		2	Homelite 7.5-kw generators (gas)		
		3	Homelite 125,000-BTU heaters		
		1	Ventilating fan, 24" explosion-proof		
		1	Homelite multi-purpose saw		
		1	Milwaukee 1/2" drill motor		
		1	Craftsman 10" table saw		
		1	Craftsman 8.8-cfm shop compressor		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Support Equipment	2	Battery chargers	Anchorage	Crowley Environmental Services
		1	10" gasoline-driven auger with extension		
		2	2-ton come-alongs		
		1	8" bench grinder		
		1	5,000-lb jack stand		
		1	7-1/4" circular saw		
		1	1/[illegible] hp jig saw		
		1	9' disc sander		
			Miscellaneous shop equipment and support gear, boom storage boxes, pre-rigged anchoring sysgems, line, personnel support kit, light kits, float kits		
	Vessels	1	Uniflite Hawser vessel - 30' x 10' x 4'		
		1	17-foot Boston Whaler		
		2	12-foot Pioneer workboats, polyethylene		
		1	17-foot Zodiac		
	Motors	1	Johnson 55 hp outboard		
		1	Johnson 50 hp outboard		
		1	Sears 15 hp outboard		
		1	Johnson 9.9 hp outboard		
		1	Johnson 35 hp outboard		
	Heavy Equipment	1	Clark 2-ton forklift		
		1	Michigan front-loader		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vehicles	1	Utility 45-foot semi-trailer (response van)	Anchorage	Crowley Environmental Services
		3	Utility 45-foot semi-trailers		
		1	International 1/2 ton pickup with canopy		
		1	GMC 2-1/2 ton van truck		
		1	Autocar diesel boom truck		
		1	Downs 40-foot lowboy		
		1	Chevrolet 4x4 carry-all		
		1	Buick station wagon		
		7	20-foot cargo vans		
		5	12-foot cargo vans		
		1	40-foot cargo van		
		1	GMC pickup		
		1	GMC 4x4 Suburban		
		1	GMC 4x4 pickup (double cab)		
	Vessels	1	12' workboat	Kodiak	
	Vessels	1	4' x 14' John boat	Juneau	R&S Pumping
		1	7-1/2 hp outboard		
	Support Equipment	2	60-kw diesel generators	Kenai	Wade's Oil Field Service
		3	Small gas generators with lighting		
		4	600-cfm compressors		
			Oil field equipment including welding and hot tap		
	Vessels	3	16' Aluminum boats	Kenai	Wade's Oil Field Service
		1	16' Steel boat		
		4	25 hp outboards		
	Heavy Equipment	3	Land cranes-rubber-tired		
		1	D-8 Caterpillar		
		1	D-7E Caterpillar		
		2	IAC 25 Crawlers		
		1	JD450 with backhoe attachment		
		1	1-1/2 yd. backhoe		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vessels	2	Workboats (14' and motors)	Anchorage	Alaska Pollution Control
	Vehicles	2	Pickup trucks		
		1	"Camper" command post and portable facilities		
	Miscellaneous	2,000	Bags, burlap		
		1,000	Bags, plastic		
		20	Buckets, 5 gas		
		500'	Chain, 3/8" galvanized		
		500'	Chain, 1/2" galvanized		
		50	Fence posts, steel		
		500'	Garden hose		
		4	Hose nozzles		
		6	Mop squeezers		
			Plastic sheeting, 30 mil		
		12	3' x 200' rolls		
		12	6' x 200' rolls		
		100	Stakes, steel		
		2	Dunlap fenders		
		6	Tarpaulin, heavy-duty, 20'x30'		
		10	Wire mesh, 1" (100' rolls)		
		1,000'	Wire mesh, 1" (100' rolls)		
		200	Wire rope clamps, 1/2"		
		50	Wire rope shackles, 1/2"		
	Work Equipment	1	Arc welder and equipment	Valdez	Alyeska Pipeline Service Company
		1	Acetylene welding equipment		
		2	Air compressors		
		4	Bird repellent devices		
		10	Blinker barricades		
		6	Generators, trailers, floodlights		
		1	Hydroblaster		
		100	Lanterns, electric		
		2	Steam cleaners		
		10	Valve, 2" l.p., Thd'd.		
		2	Weed burner, propane		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Hand Tools	4	Bung wrenches	Valdez	Alyeska Pipeline Service Company
		2	Cable cutters		
		25	Picks		
		6	Pitchforks		
		16	Rakes		
		6	Sledge hammers, 5-lb.		
		25	Shovels, sharp shooter		
	Vehicles	Quantities dependent on needs for oil spill contingency	Suburbans		
			Pickup trucks		
			Medium trucks		
			Truck tractors		
			Dump trucks		
			Motor graders		
			Loader		
			Backhoe		
			Bulldozer		
			Hilift crane		
			Rubber-tired crane		
	Vessels	3	Tugs (contracted)		
		3	Workboats (31' MonArk)		
		2	Mooring launches (contracted)		
		1	Zodiak Grand Raid Mark IV		
	Aircraft	1	DeHavilland twin otter (15 passenger) (BP/A.R.Co. joint lease)	Prudhoe Bay	ARCO
	Support Equipment	50,000'	7" drill casing		
		50,000'	9-5/8" drill casing		
		850'	8-1/2" aluminum pipe with Rolliflex wrap around couplings		
		1,500'	8" aluminum pipe with threaded connections		
		1	20' van with handtools, protective clothing, bird cleaning gear		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vessels	1	22' Flat-bottomed aluminum boat	Prudhoe Bay	ARCO
	Motors	1	33 hp Evinrude outboard		
		2	18 hp Evinrude outboards		
	Support Equipment	1	Homelite 2-kw generators, gas	Prudhoe Bay	BP Alaska
		1	Homelite 3.5-kw generator, gas		
		1	Metal van for sorbent stock		
		1	Tool house (handtools, fittings, hose, valves, hoists, etc)		
		1	Materials skid (pipe, steel, wire rope)		
		12	Assorted handtools (sets)		
			Portable lighting		
	Vessels	2	14' aluminum work boats with 15 hp outboard		
	Vehicles	1	Pickup	North Pole	North Pole Refinery
	Heavy Equipment	1	Boom truck		
		2	Fork lifts		
	Vessels	1	Boston Whaler	Juneau	Chevron USA
	Vessels	1	Barge "Tungass"-has containment boom (500') and sorbent pads	All S.E. Alaskan Facilities	
	Vessels	1	Boston Whaler	Juneau	Union Oil
	Vessels	1	Boston Whaler	Ketchikan	

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Logistics (continued)	Vessels	4	Barges (30 - 300,000 bbl)	Kotzebue	Arctic Lighterage Company
		1	20' Raider Marine aluminum boat		
	Vehicles	3	Pickup trucks with VHF		
	Heavy Equipment	4	Forklifts (1-1/2 ton - 25-ton)		
		2	Front-end loaders		
		3	Caterpillars - (2) D-6 & D-8		
	Vessels	4	Barges (30 - 300,000)	Nome	Arctic Lighterage Company
		1	20' Raider Marine aluminum boat		
	Vehicles	2	Pickups with VHF		
	Heavy Equipment	2	Caterpillars - D-6 and D-8		
		4	Forklifts (1-1/2 ton - 25-ton)		
		1	Front-end loader		
	Vessels	1	Small skiff	Unalaska	Captain's Bay Tank Farm
		1	Houseboat		
	Vessels	6	Boom boats	Ketchikan	Ketchikan Pulp Company
		1	Tug		
	Heavy Equipment		Forklifts and yard equipment		
	Vessels	2	Tugs	Sitka	Alaska Lumber and Pulp Company
		4	Bronco boats		
		1	24' Bayliner - cruiser		
	Equipment		Forklifts and yard equipment		
Ancillary	NONE				

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Emergency & Evacuation	Helicopters (See Surveillance)				
	Heavy Aircraft (See Logistics)				
	Fire Equipment	2	2-wheel, 500-lb purple "k" fire extinguishers	Cook Inlet	Upper Cook Inlet Marine Safety Committee
	Safety Equipment		Scaffolding, safety belts, floatation jackets, etc., for platform work	Kenai	Wade's Oil Field Service
	Fire Equipment	2	50-lb fire extinguishers	Anchorage	Alaska Pollution Control
	Safety	Unknown	Ambulance Fire trucks Fire crew	Valdez	Alaska Pipeline Services Company
	Safety Fire Trucks	2	American La France pumpers (750 gpm)	Prudhoe Bay	ARCO
		1	Dry chemical truck (5,000 lb)		
		1	Light water/dry chemical truck		
		1	1-ton van truck with 150-lb dry chemical extinguisher		
	Ambulance	1	Complete with all paramedic equipment		
	Safety	1	750-gpm pumper with 2,000 gallons water, 400 gallons foam, 1,500 lbs dry chemical	Prudhoe Bay	BP Alaska
		1	3,000 gallon water truck with 500 gpm pump		

INVENTORY OF ALASKAN OIL SPILL RESPONSE EQUIPMENT

Subsystem	Item	Quantity	Specifications	Location	Owner
Emergency & Evacuation (continued)	Fire & Safety	1	Fire truck foam light water, 1,000 gallon	North Pole	North Pole Refinery
		2	Fire entry suits		
	Fire Safety	1	Fire truck	Ketchikan	Ketchikan Pulp Company

APPENDIX D

NOTES ON THE BEHAVIOR OF OIL SPILLED IN ICE-INFESTED WATERS

Spilled oil immediately interacts with the environment, undergoing a series of physical and chemical changes. The nature of these changes are dependent upon the type of oil and the environmental conditions associated with the spill. The development of oil spill response scenarios is highly dependent upon the assumptions made concerning the behavior of the oil over an extended period of time. While our knowledge of the behavior of oil spilled in ice-fested waters is elementary at best, limited field and laboratory test programs have provided some insight into the problem. This appendix is a brief summary of the present knowledge of oil spill behavior in ice-infested waters in a form suitable for application to the objectives of this study. The projections of oil spill behavior prepared for each of the six arctic oil spill scenarios and the three subarctic oil spill scenarios are based on this information. The discussion on oil spill behavior is divided into the following sections:

Temperature effects on oil properties

Temperature effects on oil aging

Oil mixed with snow

Oil interaction with solid ice

Oil in broken ice fields

Oil spilled on cold water

Oil behavior in dynamic ice conditions.

Temperature Effects On Oil Properties

The composition of the spilled oil is of primary importance in determining the temperature effects on oil properties. Unfortunately, the chemical composition of oil is quite complex, and varies greatly with different geologic and geographic origins as well as the processing, if any. For the purpose of this study, three oil types have been identified as being associated with petroleum development operations in offshore Alaska. These oil types include crude, arctic diesel, and bunker C. The presence of crude oil in offshore Alaska is not yet proven and in the absence of better information its characteristics are assumed to be similar to Prudhoe Bay crude, which has an API specific gravity of 27 and a pour point of -5°F. Light fuel oil will be used for fueling the oil exploration and production operations, with arctic diesel which has an API specific gravity of 42 and a pour point of -70°F, being the most representative type. Heavy fuel oil such as bunker C will likely power the the crude oil tankers which will eventually be required for product

transportation. Recognizing that the properties of bunker fuels vary widely, bunker C was assumed to have an API specific gravity of 15 and a pour point of 50°F. It should be noted that these oil properties represent an estimate of the properties of the oil which could be involved in spill incidents in offshore Alaska. Particularly in the cases of crude oil and bunker fuels, the oil which could be involved in future offshore Alaska spill incidents could have properties which are substantially different from those selected as typical for this study. The effect of these differences on oil spill behavior could be substantial.

The major oil properties which influence the behavior of spilled oil are the surface tension, viscosity, and specific gravity. The surface tension and viscosity govern the spreading rate of the oil. The viscosity is an important property, with light oil of low viscosity tending to be absorbed more easily into materials, and highly viscous oil tending to adhere to surfaces. Viscosity also has a great influence on the choice of cleanup procedures. Specific gravity affects the ease with which the oil mixes throughout the water column. Each of these properties effecting the behavior of spilled oil must be interpreted in terms of temperature.

Surface tension increases as the temperature decreases, and can vary typically from 20 to 37 dynes per centimeter. Figure D 1 illustrates the temperature dependency of surface tension for Prudhoe Bay crude oil. Variations in surface tension play an important role in determining whether oil will spread at an interface and, if so, to what extent. Surface tension is also an important consideration when investigating the rise and breakup of buoyant plumes, as in the case of a sea floor blowout. In addition, it is important in determining the spread of one liquid over another liquid or solid, such as oil on a cold water surface, or on or under ice. Surface tension effects in cold regions have been the subject of several research programs [1 through 6].

The viscosity of many petroleum products increases rapidly as the temperature drops as illustrated by Figure D-2 [1]. Temperature dependent viscosity can have a significant impact on the outcome of a spill incident. In the winter of 1970, the barge IRVING WHALE sank in the Gulf of the St. Lawrence with a load of bunker C oil having a pour point of 50°F. The oil from the sunken barge solidified after cooling to the sea temperature of 28°F and blocked the vent pipes, stopping the leak. Cleanup procedures can also be greatly influenced by the viscosity of the oil. When the oil becomes very viscous, it does not flow and conventional pumps may not be capable of transferring the oil. Also, highly viscous oil tends to adhere to surfaces and is not easily scraped off with the result that some oil recovery devices experience reduced effectiveness when operating in oils of very high viscosity. Several reports discuss the effects of temperature on oil viscosity [1, 2, 8].

The specific gravity of oil increases with decreasing temperature, as shown in Figure D-3 for the case of Normal Wells and Swan Hills crude [3]. Consideration of the temperature effect on specific gravity is important

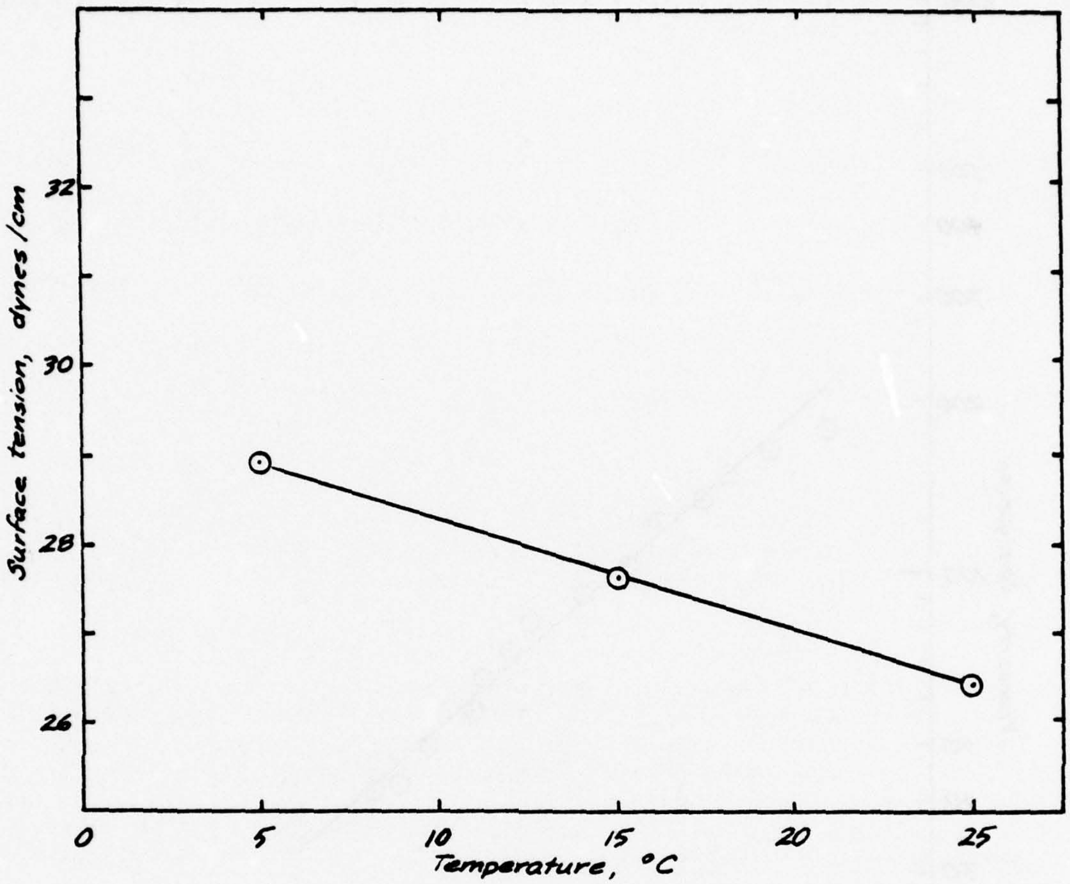

Figure D-1. Surface Tension of Prudhoe Bay Crude Oil

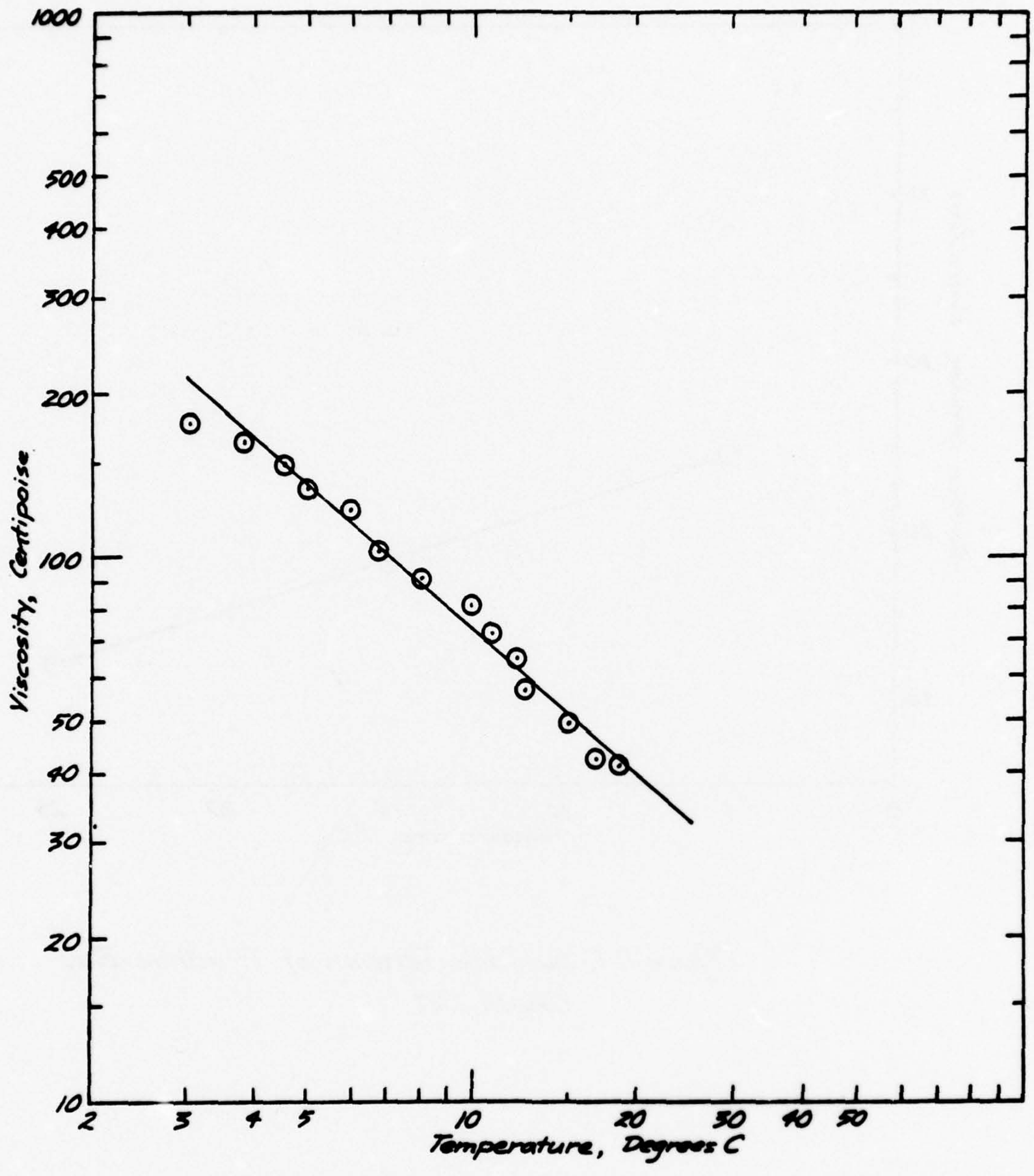

Figure D-2. Viscosity of Fresh Prudhoe Bay Crude as a Function of Temperature

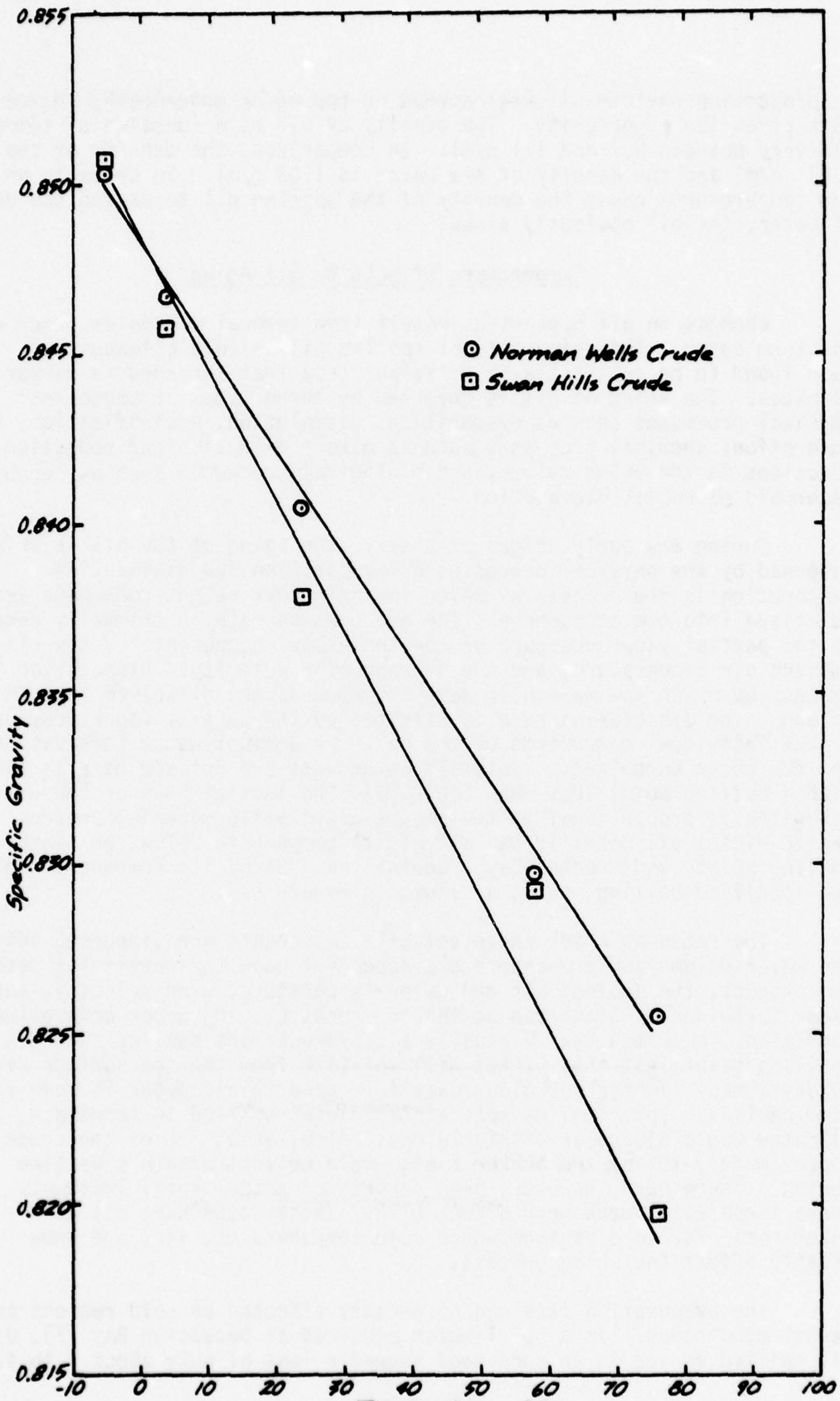

Figure D-3. Variation of Specific Gravity with Temperature

in projecting whether oil will spread on top of, or underneath, an ice cover when given the opportunity. The density of oil as a function of temperature can vary between 0.7 and 1.1 g/ml. In comparison, the density of sea ice is 0.91 g/ml and the density of sea water is 1.03 g/ml. In cases in which low temperatures cause the density of the spilled oil to exceed the density of water, the oil obviously sinks.

Temperature Effects On Oil Aging

Changes in oil properties result from several processes grouped under the term aging. The aging rate of spilled oil in cold climates has been found to be substantially different from that recorded in warmer climates. The aging of oil is governed by three types of processes: physical processes such as evaporation, dissolution, emulsification, and absorption; chemical processes such as direct oxidation and reduction reactions in the water column; and biological processes such as aerobic and anaerobic microbial degradation.

During the early stages of a spill the aging of the oil is primarily governed by the physical processes of evaporation and dissolution. Evaporation is the process by which low molecular weight compounds are volatized into the atmosphere. The evaporation rate is primarily controlled by the partial vapor pressure of the individual components of the oil, the ambient air temperature, and the average wind velocity. Dissolution is the process by which low molecular weight compounds are dissolved into the water column. The dissolution rate is affected by the partial vapor pressure of the individual components of the oil, the ambient water temperature, and the water turbulence. Volatile components are defined here as those with a boiling point less than 518°F [9]. The initial loss of these volatiles is proportional to the amount of volatile material present. Arctic diesel oil normally has all of its components below the 518°F boiling point, and Prudhoe Bay crude oil has 33% of its components below the specified boiling point as shown in Figure D-4.

The rates at which these volatile components are dispersed into the water column and atmosphere are dependent upon the particular petroleum product, the ambient air and water temperature, wind velocity, and water turbulence. Simulated weathering tests [9, 10] under controlled conditions indicated that virtually all hydrocarbons smaller than C_{15} (boiling point less than 518°F) will volatize from the sea surface within 10 days; many lighter petroleum materials tend to disappear in even shorter time periods. This implies that arctic diesel spilled in temparate climates would disappear within 10 days. Also, about 33% of the crude oil and approximately 10% of the bunker C oil would be lost within this time period. There have, however, been reports of actual spill incidents where these rates were much slower [11]. These rates have not been determined for cold regions where cold temperatures, ice, and snow greatly affect the aging process.

The evaporation rate can be greatly affected by cold regions environmental conditions. In a spill which occurred at Deception Bay [7], diesel oil spilled on ice in an open pool showed a loss of only about 2 to 4% of its

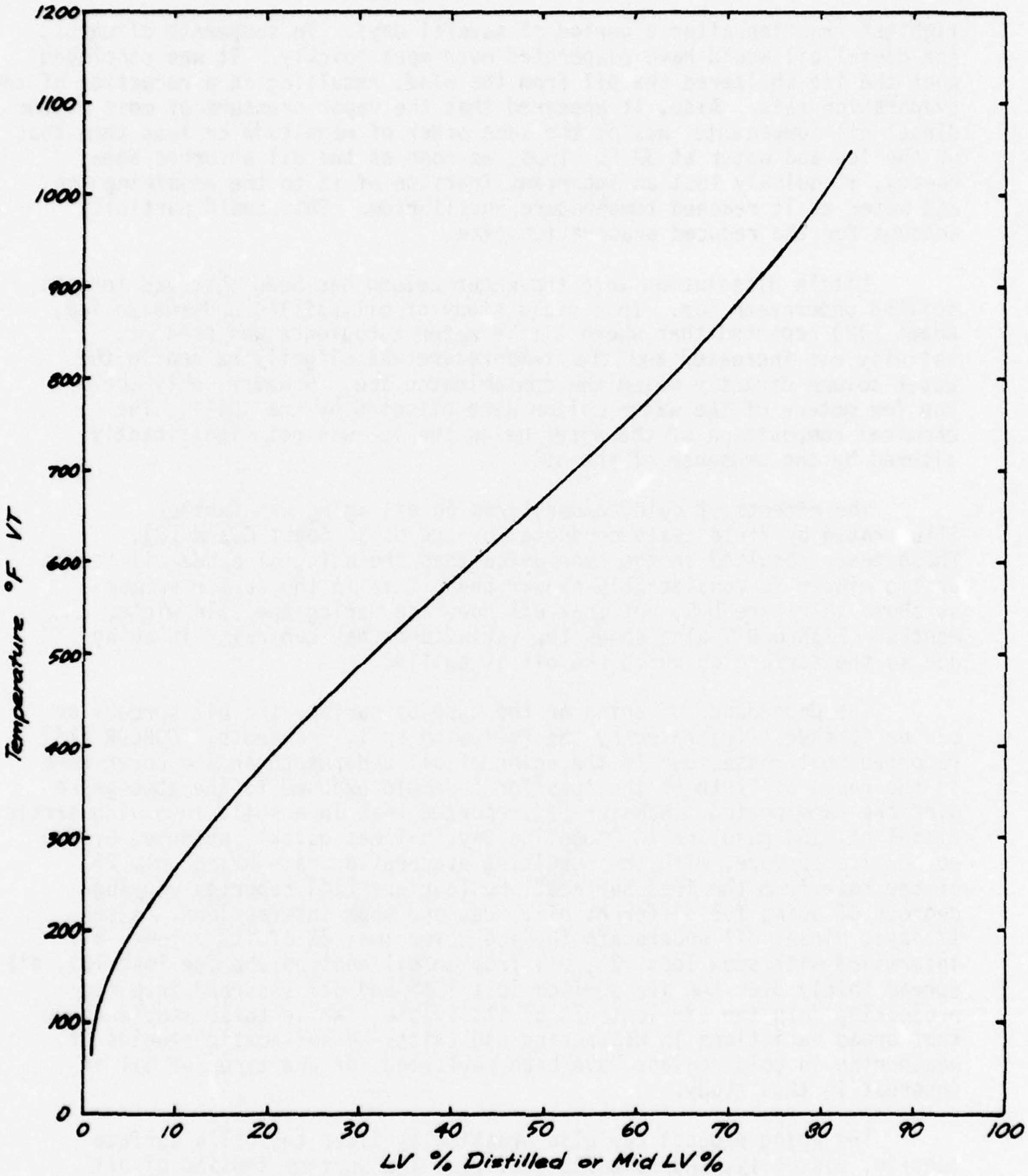

Figure D-4. Distillation of Prudhoe Bay Crude

lightest fraction after a period of several days. In temperate climates, the diesel oil would have evaporated much more quickly. It was concluded that the ice sheltered the oil from the wind, resulting in a reduction of the evaporation rate. Also, it appeared that the vapor pressure of most of the diesel oil components was of the same order of magnitude or less than that of the ice and water at 32°F. Thus, as soon as the oil absorbed some energy, it quickly lost an important fraction of it to the adjoining ice and water as it reached temperature equilibrium. This could partially account for the reduced evaporation rate.

Little dissolution into the water column has been observed for oil spilled underneath ice. In a field study of oil spilled underneath ice, Adams [12] reported that where little water turbulence was present, salinity was increased and the temperature was slightly raised in the water column directly below the contaminated ice. However, only the top few meters of the water column were affected by the spill. The chemical composition of the water below the ice was not significantly altered by the presence of the oil.

The effects of cold temperatures on oil aging was further illustrated by field tests conducted by the U. S. Coast Guard [8]. These tests resulted in the conclusion that the aging of crude oil in the arctic winter is considerably slower than it is in the warmer summer as shown in Figure D-5, but that oil does age during the cold winter months. Figure D-5 also shows the variations that can exist in aging due to the surface on which the oil is spilled.

The dependency of aging on the type of surface the oil spreads on can be further illustrated by the following spill incidents. NORCOR [13] reported that losses due to the aging of oil underneath an ice cover were in the range of 1/9th of the loss for a sample exposed to the atmosphere over the same period. Ramsier [7] reported that in a spill involving arctic diesel oil and gasoline in Deception Bay, oil was quickly absorbed by the porous ice surface, with the resulting evaporation rate being only 25% of the rate from the free-surface. Deslauriers [14] reported varying degrees of aging for different oil, ice, and snow interactions. After 12 days, diesel oil underneath the ice cover lost 6% of its volume, oil intermixed with snow lost 12%, oil from an oil pool on the ice lost 13%, oil spread thinly over the ice surface lost 30%, and oil absorbed into ice projecting into the air lost 47% of its volume. While these studies show that broad variations in weathering can exist, no systematic studies of weathering in cold regions have been performed for the types of oil of interest in this study.

The aging process can also drastically alter the oil's surface tension, viscosity, and specific gravity. The surface tension of oil increases as the volatile components are evaporated [15]. This increase in surface tension varies linearly with evaporative weight loss. Increases in the viscosity and density of oil also occur as a result of the aging process. Figure D-6 shows how the viscosity of Prudhoe Bay crude oil

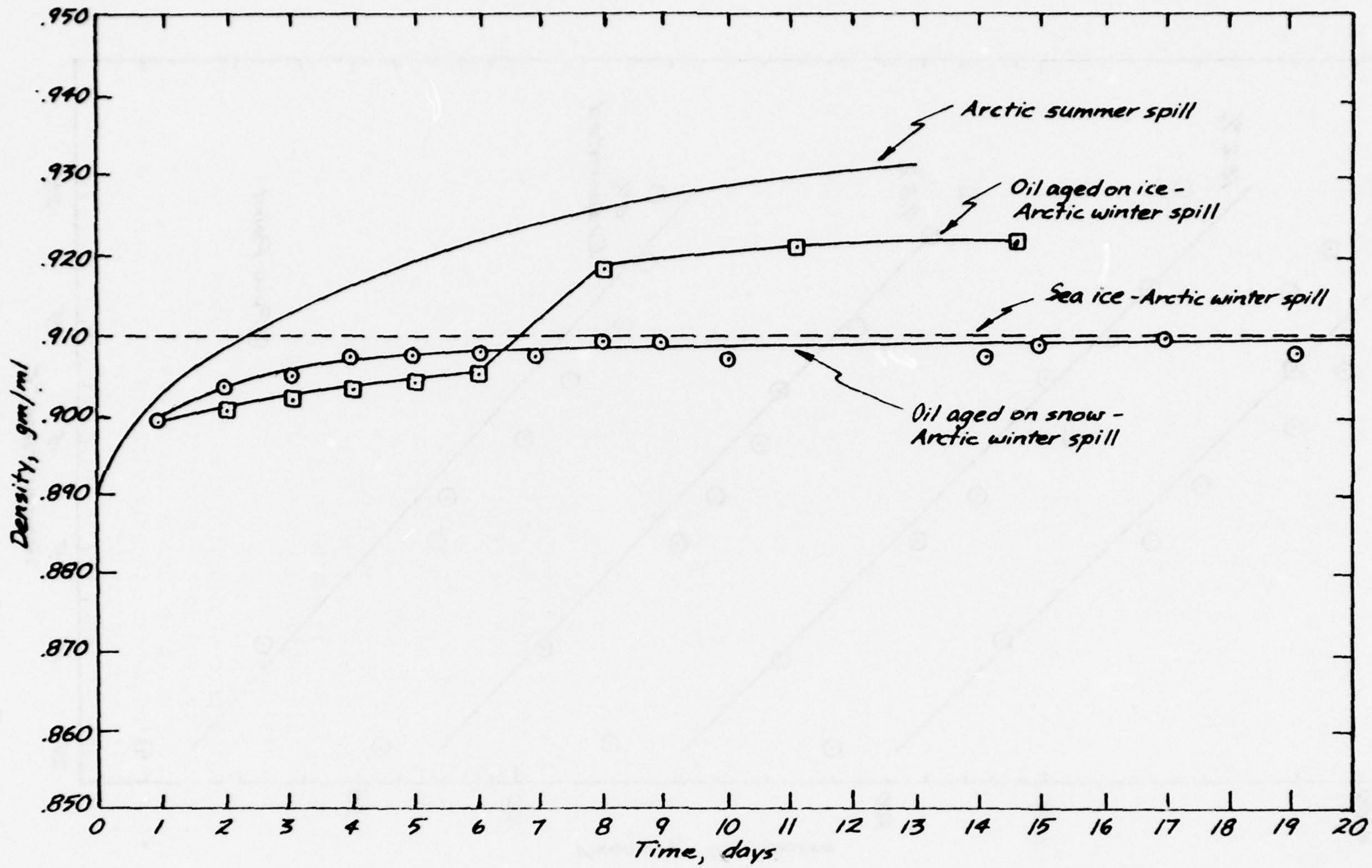

Figure D-5. Oil Density vs Time based on
U. S. Coast Guard tests [8]

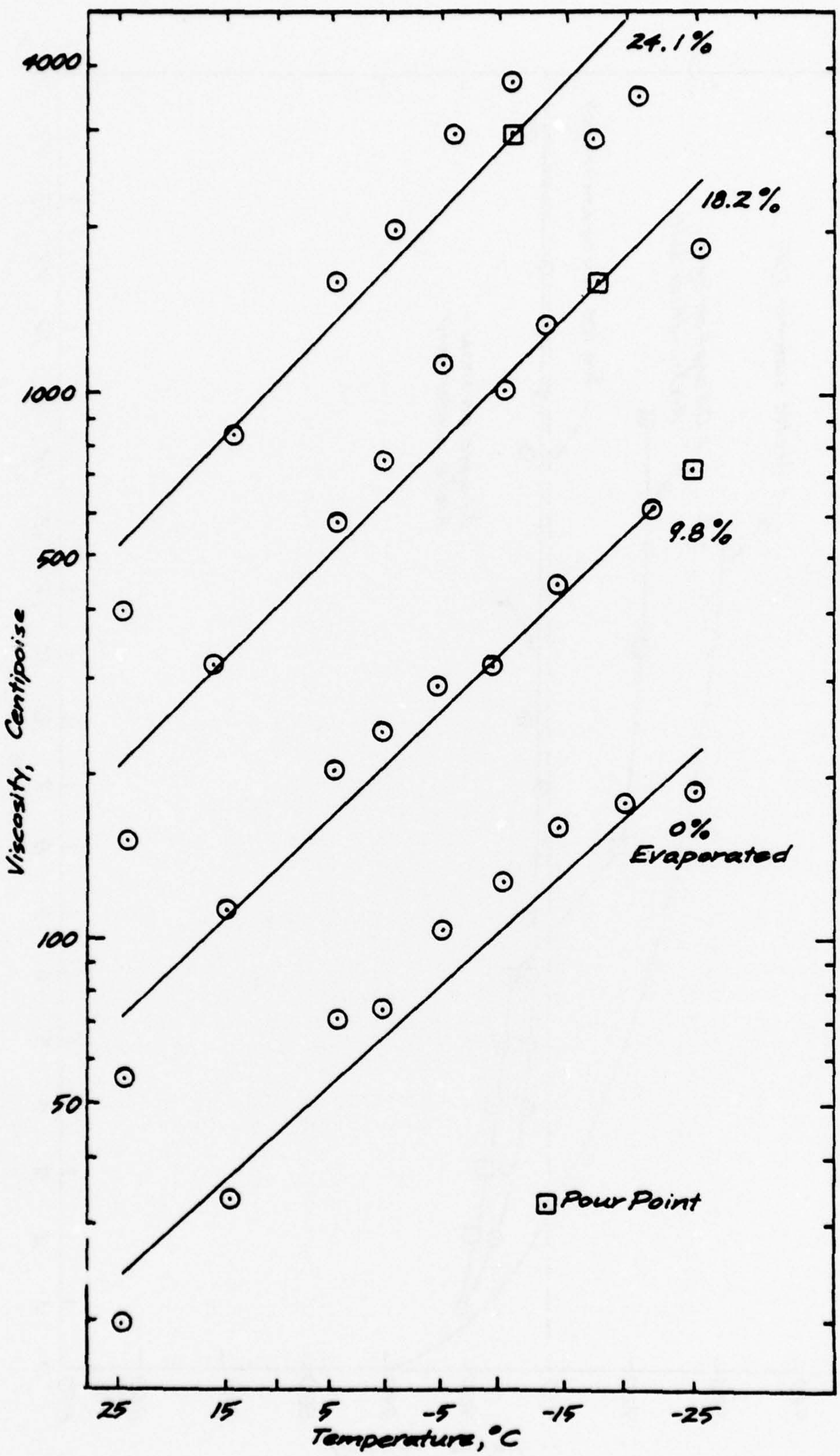

Figure D-6. Viscosity of Prudhoe Bay Crude Oil

varies with evaporation. In field experiments [16], the density of Prudhoe Bay Crude oil after five days of aging on snow or ice increased only 0.4% during the winter, whereas the corresponding increase in a summer test, when the oil aged at a faster rate, was 4.5%.

It can be concluded that a decrease in temperature will result in a decrease in the aging rate of the spilled oil. This reduced aging will result in a lower rate of increase in the surface tension, viscosity and specific gravity of the spilled oil. However, cold temperatures can compensate for this effect on oil properties by directly increasing the specific gravity, surface tension, and viscosity.

Oil Mixed With Snow

In general when oil and snow interact they mix together. This mixture may occur from snow falling on top of the oil or from oil flowing into the snow. The major controlling factors which determine how the oil and snow mix are oil viscosity, snow porosity, snow crystal structure, and temperature differences between the oil and snow [17]. If the oil has a low viscosity and the snow is not heavily packed, the oil can be absorbed quickly and to a considerable depth into the snow. High viscosity oils have a lesser tendency to be absorbed into snow. Snow that is heavily packed has a reduced absorption capability. There may even be conditions under which snow is essentially impermeable to the spilled oil.

Field and laboratory experiments conducted by Mackay [18] revealed that isothermal spills of Alberta crude oil at 32°F were readily absorbed by snow, contaminating an area of about 0.11 sf per liter of oil. Ultimately, the amount of oil that remains as a coating on the drained snow crystal will depend on the nature of the snow. It appears that it may amount to about 20% of the void volume of the snow.

When the temperature of the oil is greater than that of the snow, melt holes will form allowing the oil to penetrate to a greater depth into the snow. Therefore, hot oil spills are very different from isothermal spills. The melting process generates an oil/water mixture which penetrates the snow before the hot oil. Experiments conducted by Mackay [18] indicate that hot oil melts a channel in the snow and flows along the ground under the snow, contaminating an area of about 0.26 sf per liter of oil. This water may freeze and block further penetration depending upon the temperature of the snow. As an example, experiments conducted by the U. S. Coast Guard [19] with warm oil spilled on snow resulted in the immediate melting of the snow. The melted snow, from gravity and capillary action, moved down about 0.08 inches through the snow and refroze, at which point further downward migration of the oil was prevented.

Oil spilled on a surface and later covered by snow will behave differently. In a Prudhoe Bay crude oil spill test conducted by the Coast Guard [18], oil was covered by wind-blown snow at cold temperatures. The snow cover tended to migrate downward into the oil forming an oil/snow mulch. This mulch was approximately 80% water by volume and had a firm

cohesive consistency allowing it to be removed easily. During the 1977 Buzzards Bay diesel oil spill [14], heavily concentrated oil pools formed by rafted ice were completely saturated by snow. An oil/snow mixture was formed which was approximately 70% water by volume. This mixture could be picked up by hand without any oil dripping free. In addition, oil which is saturated with snow and covered by additional snow ultimately forms an ice/oil/ice sandwich. Much of the present knowledge of the interaction of oil with snow is contained in nine reports [8, 14, 16, 17, 18, 19, 20, 21, 22].

Oil Interaction With Solid Ice

Oil spilled on top of or underneath solid shorefast ice will behave much differently than oil spilled in temperate waters. The resulting behavior can greatly affect the type of oil spill countermeasures used. Oil spilled in solid ice conditions has been, by far, the most extensively researched oil/ice interaction. Because of the relatively large amount of information available on this topic, the discussion will be subdivided into three sections which cover oil spreading on or under ice, oil sandwiched within growing ice, and oil migration through ice.

Oil Spreading On or Under Ice

The spreading of oil on or under ice is governed by the ambient temperature; the ice surface slope, roughness, and porosity; the oil properties; and, to a certain extent, wind and water current. Under smooth ice and in quiescent waters, Rosenegger [3] found that a minimum film thickness of 0.1 inches should be expected from Norman Wells and Swan Hills crudes. Experiments by Chen and Scott [5], and Keevil and Ramseier [24] revealed that the crude oil forms film thicknesses of 0.6 to 0.4 inches beneath flat sea ice. Equations have been derived which can be used to calculate the spreading rate of oil spilled on or underneath an ice cover [6, 8, 25]. These equations are based on the oil flow rate, density of the oil, slick thickness, oil viscosity, and oil volume. From a practical standpoint, an accurate knowledge of the spreading rate may not be important since the oil in any given instantaneous spill will likely spread to its terminal area before any response action can be initiated.

The terminal area of a spill on or under shorefast ice is determined primarily by the roughness characteristics and the porosity of the ice surface. In addition, external forces, such as wind for spills on the ice and water currents for spills under the ice, can also influence the areal spread. The following paragraphs will discuss the influence of ice surface roughness, ice porosity, wind, and water currents on oil spreading on and under shorefast ice.

Sea ice generally has a rough surface caused by its initial growth from pancakes, deformation by winds and currents, and variations in the distribution of the insulating snow cover. These conditions create many

pockets and cavities in the ice. When oil is spilled on or under the ice, it will spread from the spill source filling one pocket after another. This pocket filling process has been observed in experiments conducted by NORCOR [13], Adams [12], Hoult [25], and Glaeser [1]. Kovacs [26], in a study of ice thickness profiling near Prudhoe Bay, discussed the areal coverage of oil spills as limited by the under-ice roughness. Figure D-7 is a sketch of the typical under-ice roughness distribution based upon his field measurements. The mean ice thickness during his survey was 6.3 ft. These measurements resulted in the estimation that the areal coverage of one barrel of oil spilled beneath the ice should be about 64 sf. The under-ice roughness is normally greater than the surface roughness, therefore, the ultimate size of a spill on the ice could be expected to be larger, assuming the same ice porosity and neglecting the effects of winds and currents [25]. It should be noted that the number given for the potential areal coverage of an undersea spill is based on a limited amount of data. A more extensive survey of under-ice roughness is planned.

Aside from the ice pocket filling process, the absorption of oil by the ice surface can limit the areal distribution of the oil. If the ice has a porous crystal structure, light oil would be able to flow into the ice rather freely, while more viscous oil would not penetrate the pores as easily. In a Prudhoe Bay crude oil spill test conducted by the U. S. Coast Guard [27], the porous ice surface consisting of a layer of re-crystalized ice approximately 2 inches thick was found to absorb oil up to 25% of its volume. In comparison, the Buzzards Bay spill occurred in ice which was not porous, and the No. 2 fuel oil only penetrated approximately 2 inches into the ice to a volumetric concentration of up to 5% [14].

In addition to these spreading mechanisms, the wind can also be influential in transporting oil on ice. In a spill at Deception Bay [7], wind was the most important factor affecting the spreading of the oil over the ice. On certain days the oil spreading velocity reached 50 to 60 fpm, and calculations indicated that the spreading velocity of the oil over ice due to wind was about 1/3 of that observed over open water. Also, at Buzzards Bay,wind caused oil to spread from oil pools in rafted ice formations over the surface of the adjacent ice cover.

Oil spilled under ice can further spread by interaction with currents. Little information is available on this transport mechanism, however, some preliminary work has been completed. Flume tests conducted at ARCTEC, Incorporated for the Environmental Protection Agency were directed toward investigating the transport of an oil slick under a uniformly smooth ice cover [28]. The oil thickness under static conditions was about 0.5 cm for No. 2 fuel oil, and ranged between 3 and 5 cm for Prudhoe Bay type crude oil. Under the influence of a current, the oil was neither emulsified nor entrained in the water column for stream Froude numbers between 0.03 and 0.32. Also, the oil did not adhere to the underside of the ice sheet. The tests resulted in the development of preliminary relationships between the slick velocity and the water velocity for each oil type.

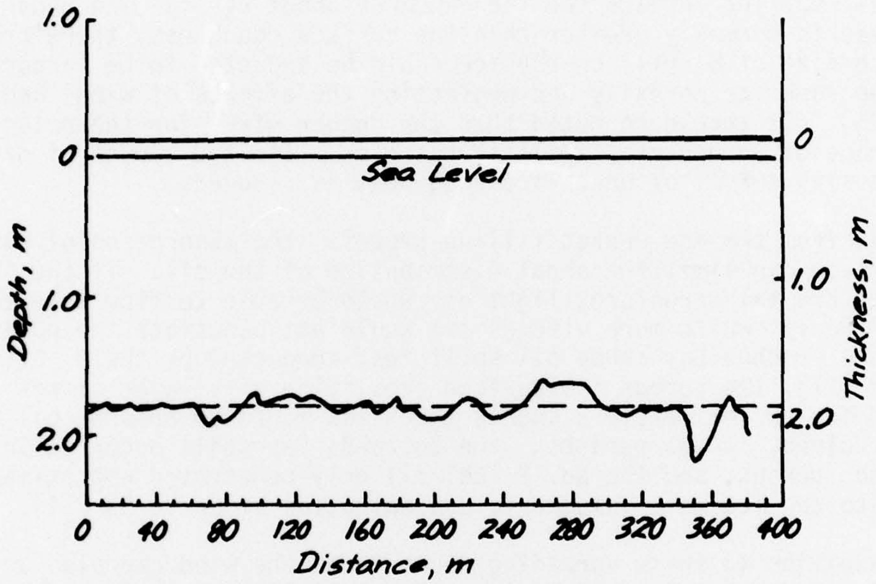

Figure D-7. First-year sea ice cross section constructed from radar data [26]

These preliminary investigations indicate that oil will move under an ice cover; however, tests have not yet determined the magnitude of the current required to move different types of oil beneath the ice for different conditions of under-ice surface roughness and for different discontinuous ice features.

Oil Sandwiched Within Growing Ice

When ice is actively growing, it will continue to grow beneath the spilled oil, forming an entrapped oil lens in the ice. If temperatures are favorable, a lip of ice forms around the lens a few hours after the oil comes in contact with the ice, limiting its further horizontal movement. During cold periods, a new layer of ice will develop beneath the oil within a few days. The fact that ice will form beneath oil that has been trapped under ice in static water conditions in below freezing temperature has been well documented [12, 24, 25, 28, 29].

In tests conducted with oil spilled on open water under ice forming conditions, an ice layer was formed beneath the oil [30]. This newly formed ice was not uniformly thick and resulted in oil pooling in the depressions. The oil was exposed to solar radiation for a period of time prior to a snowfall, and consequently had a temperature higher than that of its surroundings. Snow that fell onto the oil was then melted by the internal heat of the oil. As the temperature decreased, any water under the oil was solidified, and part of the oil became imbedded in the ice. Snow eventually completely covered the oil and became ice resulting in additional oil contaminated ice.

It can be concluded that when oil is spilled in growing ice conditions. it will nearly always be encapsulated in the ice. Oil spilled underneath ice will form an oil lens within the ice. Oil spilled on top of ice will become snow covered. The melting and refreezing of this snow will result in the formation of an ice/oil/ice layer.

Oil Migration Through Ice

During the ice decay period, the effects of the brine in the ice play a significant role in determining the behavior of the spilled oil. This brine moves vertically through the ice sheet in a desalination process. Four primary desalination mechanisms which have been proposed [31] include brine pocket migration, brine expulsion, gravity drainage, and flushing. As the sea ice grows,the desalination process tends to make the ice homogeneous in salinity. This desalination process in first-year ice creates vertical pathways through the ice, and as the ice sheet warms in the spring, these brine channels enlarge.

These enlarged brine channels allow oil to migrate down into, or up through the ice. A major field test program concerned with this vertical migration of oil through brine channels was conducted in the winter of 1974-75 at Balaena Bay, NWT as part of the Canadian Beaufort Sea Project [29]. As the ice sheet warmed in the spring and the brine channels enlarged,

the oil that was spilled underneath the ice began to migrate upwards through the ice sheet. The rate of migration increased as the level of solar radiation and the ambient temperature increased. Martin [23] observed that as the oil migrates upward in the brine channels, it then distributes itself within the brine channel network and throughout the porous surface ice. The amount of oil trapped within the ice by this mechanism was found to range between 1 and 5% by volume. Martin concluded that the entrapment of oil within the porous surface ice, and the containment of oil within the brine and feeder channels, would result in the release of oil spilled beneath first-year ice as a slow but continuous process throughout the spring and summer melt season.

During this spring and summer melt season, oil which is on the ice surface will accelerate the ice melt by influencing the temperature regime of its surroundings. The albedo, which is defined as the ratio of the light reflected from a surface to the total light falling upon the surface, would be decreased due to the presence of oil. The albedo is 0.9 for new snow, 0.6 for clean ice,0.5 for oiled snow, 0.1 for open water, and 0.1 for a solid oil lens. The resulting increased absorption of solar radiation hastens ice melting. Glaeser [27] indicated that oiled ice melted approximately 0.8 inches per day more than clean ice. In Balaena Bay [29], oil reaching the surface of the ice developed surface drainage patterns and pooled, and the ice sheet rapidly deteriorated. This study concluded that depending upon the nature and location of the ice sheet, oiled areas are likely to be free of ice between 1 and 3 weeks earlier than unoiled areas.

In conclusion, the behavior of oil spilled on and under ice is primarily dependent upon oil properties, ice surface roughness, ice porosity, wind, and water currents. Oil spilled in growing ice conditions will be sandwiched within the ice. This can occur within a relatively short time for oil spilled underneath ice. This sandwiching of oil spilled on top of ice is primarily dependant upon the thawing and refreezing of snow. Also, during the warmer season oil spilled underneath ice will migrate through enlarged brine channels to the ice surface. Oil on the ice surface will hasten ice melting due to solar albedo effects.

Oil In Broken Ice Fields

The characteristics of broken ice fields vary widely in both ice piece size and concentration. Broken ice fields can include slush ice, pancake ice, large sections of broken shorefast ice, or multi-year ice. The behavior of oil spilled in broken ice fields will depend upon the ice and oil type, ice concentration, wind, waves, and currents.

During the initiation of ice growth, small salt-free crystals of ice called frazil ice, form on the water surface. At first they flow freely, but later mesh together to form a thin mushy layer. This frazil ice tends to remain a fluid, porous mass up to a thickness of about 5 inches. The ratio of the volume of the ice to the total volume of sea water in the

ice ranges from 35 to 40%, so that frazil ice can typically be about 60% sea water. Laboratory experiments conducted by Martin [32] reveal that slush ice also has a high porosity. The experiments suggested that oil will rise through the slush ice and spread on the surface without any signs of oil absorption below the slush ice surface. Based on these tests it appears that oil spilled in these conditions would have to be recovered with, or separated from, the frazil ice it is floating on.

As slush ice continues to grow, it eventually forms pancake ice. The size of the pancake varies from 1 to 2 ft in diameter. Several pancakes will then freeze together forming the first floes which may attain dimensions on the order of 3 to 10 ft. Oil spilled within pancake ice will flow between the ice pieces. Waves create an oscillatory motion of the pancakes, which tends to pump the oil away from its original discharge point. Oil is pumped both onto the surface and along the cracks between the pieces of ice. Oil spilled in these conditions will be concentrated in the open water between the pancakes, and along the edges of the ice pancake surface.

Test spills of crude oil with properties similar to Prudhoe Bay crude and of No. 2 diesel conducted in a simulated broken ice field of 95% concentration with ice pieces ranging from 12" x 12" x 20" to brash showed that the oil would tend to gather between the ice [33]. When crude oil was poured in the broken ice field, it built up in thickness between the ice pieces rather than spreading. After 24 gallons of crude were deposited, the slick covered an area of only 30 sf. On temperate waters, the same volume would cover approximately 300 sf. The oil thickness in the center was 3.75 inches, and thinned to about 2.5 inches near the boundary. No. 2 oil was spilled under the same conditions and it spread rapidly through the broken ice field to form a much thinner layer. The equilibrium thickness of oil spilled in a static broken ice field is therefore highly variable, likely being a function of the properties of the oil, the concentration of the broken ice field, and the size distribution of the ice pieces.

During the 1977 Buzzards Bay spill [14], diesel oil which was incorporated in the relatively stable ice began to be released upon breakup. The ice floes which resulted contained various amounts of oil. As the ice floes further deteriorated, oil which had penetrated into the ice streamed from the floes in the form of sheen. This allowed the oil to travel a considerable distance with the ice in some instances before being released into the open water. Contaiminated ice floes which drifted into coves settled on the beaches and leaked the oil into the sediments and beach grasses.

In the 1977 ETHEL H spill on the Hudson River [34], No. 6 oil also interacted with a broken ice field. Prior to the spill, ice floes created from the breakup of the shorefast ice covered 80% of the river at some locations. As these ice floes traveled down the river, it was observed that heavy tarry oil adhered to many of the ice floes. In some instances, the ice surface was 50% covered with oil.

A thin sheen of oil was observed streaming from some of the more heavily oiled ice pieces. When the ice floes became packed together, the oil between the floes was contained to a greater thickness. As the contaminated ice left the mouth of the Hudson to enter the Atlantic, the heavy oil would move along with the broken ice and bleed off oil in the form of a sheen.

From these observations, it can be concluded that diesel oil spilled in a broken ice field will penetrate into the ice and flow between the ice pieces, depending upon the concentration of the ice field. Crude oil spilled in broken ice conditions would typically adhere to the ice surfaces and bleed oil sheen, or the lighter ends, into the surrounding waters. The heavier crude would have a far greater tendency to be contained by the broken ice pieces with a resulting greater oil thickness. If there is enough interaction between the crude oil and ice, all of the heavy ends of the oil could possibly adhere to the ice surfaces. The oil which adheres to the ice would cause melt pockets or holes to form in the ice surface during warming periods due to the albedo differences.

Oil Spilled On Cold Open Water

Oil spilled on open water in cold regions would behave differently from that spilled in temperate climates. In particular, cold temperatures affect the oil properties in a manner which tends to increase the terminal thickness of the oil and reduce its spreading rate. Oil spilled on open water in a lead in the ice cover would most probably come in contact with the ice edge. This discussion will be separated into the spreading of oil on cold open water, and interaction of oil with an ice edge.

Spreading On Cold Open Water

The initial spreading and subsequent transport of spilled oil by winds, waves, and currents will direct the slick on the water surface. The spreading of light oils on the surface of open water can often be very rapid, requiring spill response to be prompt if any oil is to be recovered. Such oils spread to a monomolecular thickness, becoming invisible to the naked eye at a thickness of 1.5×10^{-6} inches. Tests conducted by ARCTEC, Incorporated for the U.S. Coast Guard [33] showed the thickness of Prudhoe Bay type crude oil at 0°C to be 0.29 inches. Therefore, spills of more viscous oils on cold water will primarily differ from spills occurring on warmer waters by having a greater oil thickness. The resulting transport of the oil slick by wind, waves, and currents should be similar to that experienced in warmer climates.

Interaction Of Oil With An Ice Edge

Oil coming in contact with the ice edge can flow either underneath the ice, be emulsified in the water column, flow on top of the ice, or be contained by the ice. Factors which determine the direction the oil will take include the forces pushing the oil against the ice, the specific

gravity of the ice and oil, and the ice edge thickness. From a spill response standpoint, it would be preferred to have the oil contained and concentrated along the ice edge. Examples from past spills will be discussed to illustrate the effectiveness of an ice edge in containing oil.

At the Chedabucto Bay spill [21], oil was observed at the leading edge of the ice and did not appear to move under the ice for any significant distance, even under persistant winds. Only small amounts of oil in particulate form were observed under the ice at some locations. Tidal currents were small, and thus the ice served as an effective barrier to oil spreading.

In an oil spill in Deception Bay [7], the oil tended to flow into open water tidal cracks where the water was much less turbulent than it was in the open sea. The ability of the water in the tidal crack system to emulsify and disperse the oil was limited, but it was not completely eliminated since there was evidence that some oil had been dispersed and carried a substantial distance under the ice. The emulsification resulted from the tidal motions and the wind. Studies indicated that the production of emulsions requires a threshold level of water turbulence. [20] The presence of residual oils and low temperatures, producing high oil viscosities, aid the emulsification process [20].

The previous examples showed that the ice edge can contain oil; however, the currents associated with these examples were not high enough to cause complete containment failure. At the 1977 Buzzards Bay spill [14], observers on the leaking barge noted that as the oil was released it built up along the edge of the ice surrounding the barge, and was forced under the ice by strong tidal currents of 1 knot. Once under the ice, the currents transported the oil laterally.

These observations illustrate that the ice edge can serve as an effective containment barrier under certain conditions. However, the conditions required to cause emulsification, entrainment in the water column, and transport underneath the ice, have not been defined.

Oil Behavior In Dynamic Ice Conditions

Oil behavior in ice infested waters is strongly dependent upon the dynamic character of sea ice. Ice which is not fastened to the shore or bottom responds to the wind and current stresses by moving and reshaping, with the possible formation of pressure ridges, rubble fields, and hummocks. Little experience has been gained in observing the behavior of spilled oil in dynamic ice conditions. A spill of diesel oil which occurred in 1977 at Buzzards Bay [14] allowed researchers to investigate the interaction of oil in rafts, hummocks, and ridges.

During the 1977 Buzzards Bay diesel oil spill, nearly all the oil being transported underneath the ice settled within two days into rafts,

hummocks, and ridges where it was sheltered from the strong tidal currents. The oil remained fairly stable in these formations until the ice began to break up. Rafted ice led to the formation of oil pools with depths of up to 0.5 ft on the ice surface. These pools held approximately 30% of the oil spilled in the Buzzards Bay incident. The formation of these pools occurred within a day of the spill, and was unexpected on the basis of previous work on oil spills in ice. The sequence of sketches in Figure D-8 shows a possible oil capture scenario. As the current carried the oil under the ice, the oil encountered the bottom of the rafted formations where it was sheltered from the current in the lee of the submerged part of the raft. The buoyant oil then rose through an opening between the two ice sheets to replace the heavier sea water in the pond. Once on the surface, the oil was protected from the currents. As the tidal current oscillated back and forth, the fuel which was not protected from the currents was then swept away. The oil pools which formed contained as much as 2,000 gallons of oil.

It was also observed during the Buzzards Bay incident that the oil could have interacted with pressure ridges and hummocks in two ways. The first way occurs when oil is incorporated during the formation of the pressure ridge or hummock. This happens when small contaminated ice pieces are compressed together into a pressure ridge or hummock creating a pile of oiled ice pieces. It also happens when oil in a lead along the ice edge is squeezed and coats the ridge walls during the formation of the pressure ridge or hummock. Numerous observations point out that flat ice bending down at the ridge base could yield another possiblity for oil entrapment. Secondly, oil can flow into previously formed pressure ridges and hummocks as shown in Figure D-9. The porous pressure ridges and hummocks create numerous small crack systems for the oil to fill in hydrostatically, thus allowing the oil to coat the ice and settle within the crack systems. If the keel from a ridge or hummock is not porous it can also provide a means for the containment of oil [35]. It appears that a ridge or hummock may contain oil in volume depending upon the currents, oil properties, ice properties, and porosity of the ridge or hummock.

It can be concluded that if the oil is spilled under the ice and is transported by currents it may concentrate in rafts, hummocks and ridges. If the oil is spilled in a lead, subsequent ice deformation will also tend to concentrate the oil in discontinuous ice features.

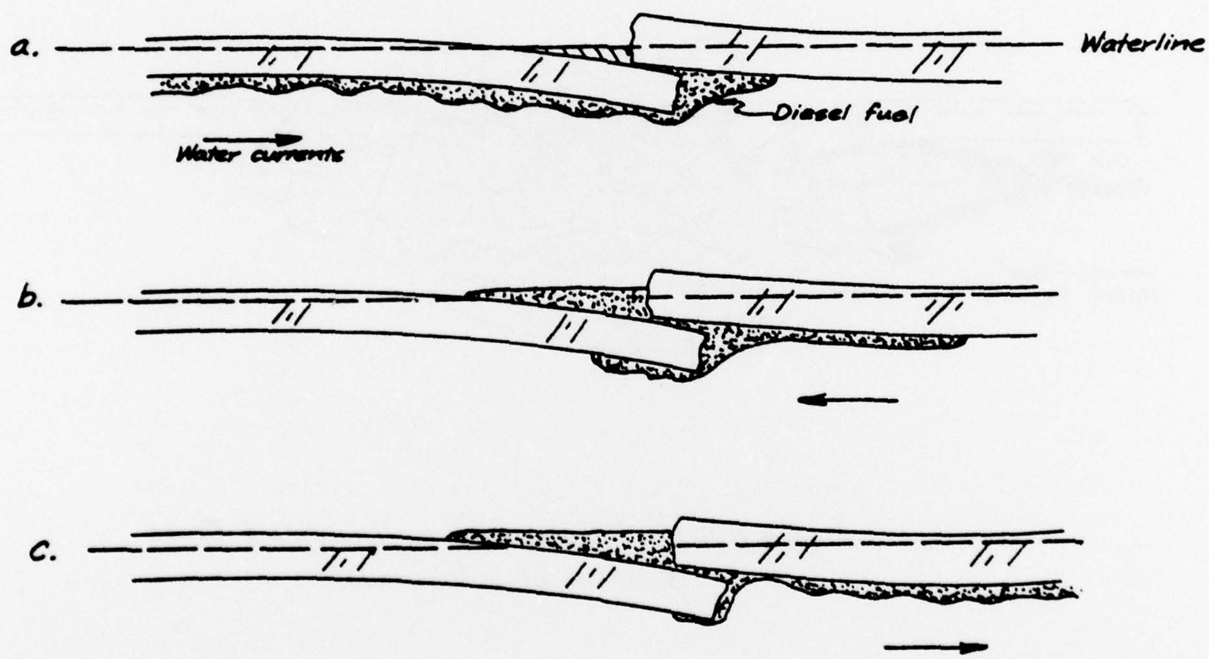

Figure D-8. Flow of Oil in Rafted Ice a.) Oil flowing underneath the ice comes in contact with rafted ice. b.) Current reversal encourages oil filling into rafted ice pocket c.) Reversal of current sweeps unsheltered oil away

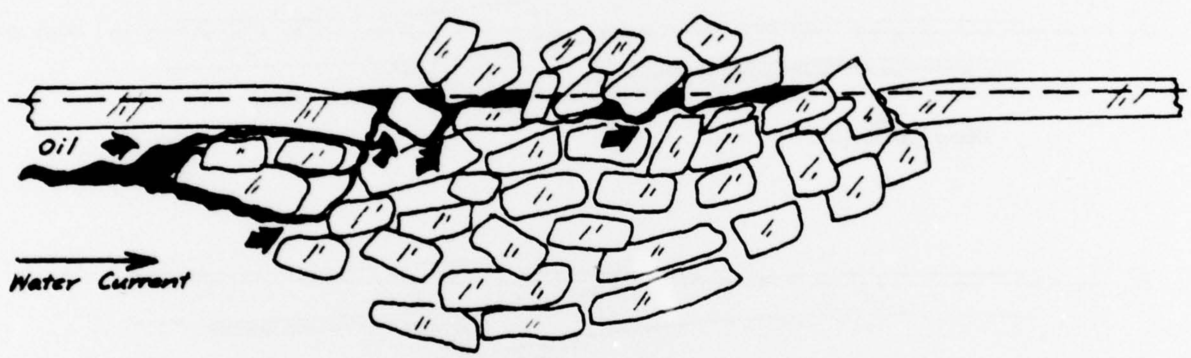

Figure D-9. Oil Flowing into an Idealized Cross Section of a Hummock

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